The Journal

OF THE

Royal United Service Institution.

Vol. IX. 1865. No. XXXIV.

Evening Meeting.

Capt Caldwell

Monday, February 28th, 1865.

Captain E. G. FISHBOURNE, R.N., C.B., in the Chair.

3 Rutland Sq

MODERN NAVAL TACTICS.

By Commander P. H. Colomb, R.N.

The steady advance and final adoption of steam as a necessary appliance of naval warfare has brought in its train a vast variety of changes, whose approach had been unforeseen, and for whose reception, even when recognized, the preparations have not been altogether adequate. Recognition of a change has been more or less tardy in proportion as the necessity for it made itself less or more strongly felt. But, although in civil affairs, the pressure enforcing a change is usually in equal ratio to its importance, and therefore, if the premonitory symptons produce their natural effect the change is made before the evil consequences of delay have had time to act; in the affairs of war it sometimes happens that the importance of an object is not generally admitted, and in rare cases not even suspected, until either some terrible calamity to a nation's arms through the want of sufficient capacity to appreciate facts, or some splendid success, rifled from the hand of fortune by a master mind, show that the failure or the success were equally the result of a neglect of, or an intelligent use of facts, which were at the outset common property.

Thirty-three years had steam itself been toiling upwards in our fleet in times of peace; almost belying the few who steadily predicted its triumph, until the outbreak of the Russian War, with a suddenness never equalled, swept away for ever the notion of a sailing fleet, and set the workshops of England going, to turn out with all speed those hundreds of marine engines which the years 1854–5–6 saw created.

A lost Austrian war, and an easily overrun Danish territory, are historically connected with lack of rifled and heavy ordnance. Nor will the annihilation of the "Cumberland," in the waters of the Chesapeake, or that more recent and more sudden destruction of a Confederate ship, the "Albemarle" by a torpedo, be considered by our countrymen as disconnected from any failure of our arms in future cases of the like nature.

A great service like our navy can by no means afford to lag behind in a full appreciation of the facts which surround its position, and which will inevitably govern its proceedings in any future naval war; for though no sensible man can see the seeds of decadence in our maritime prowess, or can anticipate aught but ultimate success to our arms, we are proverbially liable to early reverses or indecisive successes at the commencement of hostilities; and we really cannot foresee the consequences of an ill-commenced naval campaign with the costly and elaborate appliances of modern warfare.

It is therefore important that we should, from time to time, study and endeavour to master, the probable effects in future wars of those changes in the material or moral condition of the navy, which are either finally established, or whose establishment seems certain within a reasonable time. More distinctly should attention be directed to the solution of those questions whose importance is very great, but whose pressure for solution in the quiet times of peace is either slight or altogether absent. Of such a nature is the subject with which I have this evening undertaken to deal.

I envy no naval officer who thinks the science of tactics is rightly placed in the shade to which our navy has tacitly condemned it; nor can I avoid fearing that, unless some English labour, commensurate with that of foreign growth, is bestowed upon it, we may one day have cause for repentance.

Like all cases in which scientific truth finds the path barred by the inertia of settled ideas, there have not been wanting, from the earliest days of steam, a succession of advocates calling for the necessary dispositions to meet the changes it was working in our fleet manœuvres. Whatever the results of this advocacy may have been in foreign navies, our own, it cannot be denied, has taken very little notice of the subject; and, if our only official treatise, the General Signal Book, represents the embodied wisdom of the navy in this behalf, it may be well should we discover that the wisdom of foreign navies goes no further.

In 1846 Admiral Bowles, in a forcible pamphlet, showed the necessity of modifying the old systems of tactics, and carefully studying those probable in future. The late Captain Moorsom followed in 1854 with a small work; and in France Count Boûet Willaumez wrote his *Essai de Tactique à Vapeur*. This was soon followed by the French official *Tactique Navale*, translated into English in 1859; and it is worthy of note here that the French Evolutionary Signal Book, founded on this manual, is corrected, year by year, as the experience of the squadron of evolution appears to direct; a course which, if honestly carried out, can hardly fail of satisfactory results.

In 1858 the late Sir Howard Douglas gave us his *Naval Warfare with Steam;* and Sir William Martin printed for private circulation some remarks on steam evolutions, which later were made the basis of a complete system.

One result of these contributions to the science was a slight modification of our General Signal Book in the new issue of 1859. A few purely steam evolutions were added, and an endeavour was made to arrange the wording of the old sailing instructions and orders, so as to embrace the new circumstances. Sir William Martin, with the Mediterranean fleet, now carried out a series of very important experiments, and drew up a complete scheme—which I think it is a subject of regret has not been moie generally circulated in the profession.

Whilst England and France were thus contributing to an elucidation of the questions involved in the matter, Russia was, under the auspices of a renowned and gallant officer, carrying out experiments which extended over four years, and which resulted in the publication of Admiral Boutakov's "*New Basis for Naval Tactics*"—a work of which the recent translation into French, has rendered it available for our purpose. Every one who has read this work must agree in thinking it a very remarkable addition to our knowledge. Opinion may be divided in the English navy as to the practicability of the views advocated, but I think it can be shown that the writer has raised questions, a right understanding of which, will for the future form the foundation of our fleet movements.

It will be readily premised that in a short paper like the present, it is not possible to deal with such varied and complex questions as the subject brings before us, except in the most cursory and general way. I propose, therefore, to treat only of the leading principles which appear to govern the theory and practice of the science.

I am not one of those who think that a system of tactics can be produced off hand, nor do I wish to give the product of the study a weight greater than its due. Experiment, and experiment only, can solve most of the questions propounded to us, but we can undoubtedly, by careful study and discussion smooth their course, and assign the limits beyond which they need not pass.

I believe, however, that it is only those who have given much attention to the matter who are fully alive to its intricacies and its generally unsatisfactory character; that consideration should, however, stimulate our efforts, as the importance of a solution is at the least commensurate with its difficulty.

The subject naturally divides itself into two great branches, which for the purposes of this paper may be separately headed: with the proviso, however, that their connexion being really most intimate, this separation is only excusable on the ground of clearness. The two branches may be termed the *mobilization of fleets* and *naval strategy.*

Most modern writers on the science have confined themselves to the consideration of the former part, naturally avoiding the vagueness and uncertainty which clings to the latter. Were it possible to ascertain with precision the forms in which fleets will in future

prepare for attack and defence, *naval strategy* would properly form the basis of the whole subject, just as in old times the *line of battle* being established as the universal fighting order, all others were valued on their capacity for speedy conversion into that normal attitude. As it has never been possible since the introduction of steam to assert positively what the normal position of a fleet will be, and as it now seems more than ever uncertain, most authorities have been content with the very wide basis of all possible forms of attack and defence for their systems; and their only endeavour has been to show how from any given formation in any given direction, a fleet may, by the use of many diverse movements, pass to every variety of position or direction which is possible. This proceeding has, I think, somewhat embarrassed students, for it is difficult when a great variety of considerations are placed before us on the same level, to attach to them their relative values, or to ascertain their bearings upon each other.

Under these circumstances, I propose to examine first the movements of bodies of ships acting in concert; then the modes by which this concert may be best secured, and lastly, I shall devote a short space to the consideration of future naval strategy.

With one exception, all modern tacticians have drawn a complete line of demarcation between steam and sailing tactics; but this seems hardly a judicious mode of treatment; for as stated by a distinguished tactician, "there is such an analogy between the power of changing positions in a squadron sailing free, and in another propelled by steam, that the principles which regulate the evolutions of the one, will govern those of the other." The value of this observation lies in a deduction from it that this similarity of movement may be made the medium of conveying instructions to officers which might otherwise be unattainable. The value of the most carefully devised rules in tactics, is materially diminished by the absence of practice in their application, and it is therefore no unimportant part of a tactician's duty to provide, in the every day movements of a fleet in peace, that practice which will stand us in such good stead in the enemy's presence. Evolutionary drill of a large steam fleet is so expensive* a matter that no nation can practice it to any great extent in time of peace; whilst in war time the efficiency of a fleet will depend so completely on its supply of fuel, that our admirals will be very chary of its expenditure for drill purposes.

These considerations seem to point out that one of the very first objects to be striven for in the arrangement of a system of tactics, should be the incorporation of sailing into steam tactics. Not to graft, as has already been ineffectually attempted, the new system upon the old, but to frame an entirely new system of steam tactics, and to take in so much of the sailing systems as may be possible without confusion. Masts and sails have now assumed the position of a true auxiliary power, which twenty years ago was thought the

* "Edgar," at 8 knots, burns 2¼ tons per hour, say 48 tons per day, at 15s. per ton. With 12 ships, equal £432 per day.—P. H. C.

final position of steam, so that tactical arrangements should be based upon those inverted values.

Were any further argument needed to enforce the propriety of this course, we have it in the fact that modern fleets are constantly under steam and sail both, and that if either the movements themselves for each power, or the orders directing them are not identical, there remains an alarming source of error and confusion. It is more generally admitted now than formerly that the difficulty of preserving order in a fleet has not been reduced by the advent of steam. The increased size of the ships has no doubt contributed to this result, but beyond this, as the speed of each steam ship depends on a force within herself, and only partially under the control of the officer in command, whilst the speed of each ship in a sailing fleet depends upon a force which is common to them all, and whose effect is strictly under the control of those responsible for her station, it is evident that a steam fleet is more liable to disintegration than a sailing one.

The assertion that the maintenance of a uniform speed is the first requisite in a mobile fleet, requires no comment; and if this be difficult of attainment at present, some means should be sought to effect it. Would it not, for instance, be possible to place the control of the throttle-valve in the deck officer's own hand? Something would be gained by the employment of a dial under the eye of the officer of the watch, upon which by means of the pressure corresponding to her passage through the water, the ship's speed at any moment could be ascertained. Might it not even be possible to connect this force directly with the throttle valve, so that any given speed might be accurately maintained, the instrument acting as a governor upon the engines? Such an arrangement would doubtless contribute both to the security of the engines, and the saving of fuel.*

Admiral Boutakov considers that uniformity of speed may be obtained sufficiently close for practical purposes, by causing the fleet to steam in line abreast for a short period, and regulating the speed upon the slowest ships. After the determination of this "*question capitale*," as the Admiral calls it, the next point is to establish uniformity of evolution under the action of the helm.

Until Admiral Boutakov wrote, this most important element was either quite overlooked, or very scantily dwelt upon by tacticians, but that Officer has now pointed out with remarkable clearness and elaboration how completely the celerity and precision of fleet movements depends upon a proper understanding and application of the laws which govern the path of a ship when acted on by her helm. The Admiral states that having at first "resolved the problem in a manner quite as inefficient and arbitrary as those who had entered the lists with him on the subject," he soon "struck upon the very simple idea that every evolution of steam ships was inevitably based upon

* Since writing the foregoing, I have learned that Admiral Bullock has invented a dial log of the kind mentioned, which may be seen at Potter's, in the Poultry, and which it appears very important should be tried in a fleet.—P. H. C.

two geometrical lines, *the circle* and *the tangent to the circle*." This idea he terms "the root" of the question, and although many English naval officers will consider he has unnecessarily elaborated the theory, I hardly think any one who reads the work can fail to be very much struck with the arguments put forward. It will not lighten the weight his views may have, to be told by the writer that, in the laws pointed out, we have "an easy means of manœuvring with rapidity, exactitude, and perfect regularity, and that this has been proved by the captains of the squadrons commanded by the gallant officer, *during four years of experiment.*

It is a well known fact that a ship steaming ahead with her helm over, describes a curve so nearly resembling a circle that for all practical purposes it may be taken as one. The diameter of this circle can be increased to any extent by diminishing the helm, but its decrease is subject to considerable limitation. *The smallest circle in the shortest time*, is described by a screw ship when going full speed with her helm at an angle of 45°. Every diminution of speed increase the *time* but decreases the *diameter* of her circle; whilst every diminution of the helm increases both the time and the diameter of the circle described.

Fig. 1, Plate I, gives a comparative view of the circles described by a gunboat going full speed, with the different degrees of helm marked against each. The diagram is prepared from a series of experiments conducted by Captain Key in 1862, who kindly furnished me with the results, and from which I draw most of the conclusions here given. That diagram shows us very distinctly, not only the importance of the enquiry we are now making, but also the beneficial results to be expected from increased power over the helm.

Before we can ascertain the exact bearing of the laws just stated upon the subject before us, it becomes necessary to apply them to the classes of ships which now, and for many years to come must form the main body of our fleets.

Table 1 is an extract from some I have drawn up on the data given by the experiments just quoted, and which furnish the only valuable facts I know of, connected with the matter under discussion. Admiral Boutakov in his table of the calculated circles of ships uses this proportion :—As one hour is to the time occupied in describing the circle, so is the speed per hour to the circumference of the circle. Applying this proportion to the calculation of the circles of a gunboat steaming 7 knots, and whose period of revolution for various degrees of helm is given in the second column of the table, we get the circles whose circumferences are given in the third column: but the actual circles, which were carefully measured, are only of the circumferences given in the fourth column. We see therefore that a certain retardation takes place, due to the resistance of the rudder, and that a considerable reduction must be made from the calculated circles, in order to obtain the real ones. This correction in the form of a multiplier is given in the last column. The experiments were tried with several areas of rudder, and though their object was different from that for which I am now using them, enough data are given to

show that the corrections apply approximately, whatever the area of the rudder may be, which leads me to suppose there is a fixed law governing the motion of all classes of ships under helm action, which law when discovered, may be usefully applied.

Even the small portion of the experimental results I have placed before you, point out the possibility of expressing the variations in time of evolution, and diameter of the circle in terms of the rudder angle. Investigation, so far, has satisfied me that this law is contained in the following statement. *The diameter of the circle varies inversely as the sine of the helm angle, and the period of revolution, directly as the cosine of the angle.*

In table 2 are a few of the times and diameters calculated on this theory compared with those observed, which seem to bear out the truth of the idea.

Whatever corrections larger and more accurate experiments might bring to the data given in the tables before you, I think I am fully justified in assuming their truth for the present, and in using them as I have done in preparing the diagram (fig. 2, Plate II).

We have here represented the inversion of a column of six ships of the modern class, just as it might be expected to take place under present circumstances; and I do not think any comments of mine could increase the force with which that diagram appeals to us. To my own mind it brings conviction of the importance of the prints first publicly put forward by Admiral Boutakov. The absolute confusion into which a column is thrown during the process of inversion is well shown by the shaded vessels, each of which is in the given position at the moment when the "Royal Oak" has completed her half circle.

We have thus reached the second stage of our inquiry. Not only must a uniformity of speed be secured, but a uniform radius of evolution must be sought for. Movements must be regulated by the slowest ship in the one instance, and by that describing the largest circle in the second.

Admiral Boutakov states that this uniform radius is obtained sufficiently near for practical purposes by inverting the line "together" several times till the ships fall into their proper places, and then each ship marking the position of her helm, and in all future movements using that angle.

I have thought, however, that if some circle of evolution were permanently fixed for two or three classes of our ships likely to be acting in concert, the proper helm-angle for each individual could be calculated and marked upon the tell-tale; then all confusion would be avoided on any number of one class coming together.

Throughout the rest of this paper I consider that uniformity of speed and radius of evolution have been attained; and for convenience I assume this radius to be 200 fathoms, the established distance apart for ships in column Whatever the radius be however, the relative bearing of the facts to be adverted to, remains the same.

It should be here stated also, that in all the diagrams given, the unshaded ships represent the position of the fleet before manœuvring; the shaded ships, any intermediate stages it may be necessary to

mark; and the black ships the final position of the fleet on completion of the manœuvre. In this arrangement I follow Admiral Boutakov, and should express my obligations to him, not only for this, but for the very large draft I have made from his *Nouvelles Bases* for the purposes of this paper.

The change of position of a column of ships proceeding in any direction is effected either by the helm, by a variation of speed, or, finally, by both continued. Variation of the helm is not only capable of being determined with greater accuracy than variation of speed, but its effects are made more quickly as well as more distinctly visible by reference to the fixed line supplied by the compass. Again, as every ship in a fleet must continue in motion in order to preserve its relative position, the process of taking up a station with reference to any particular ship must always be a matter of some complication so long as the moving object is to be the guide. When, however, the courses of the ships are parallel, there is not such difficulty, as a reduction or increase of speed will effect the object. If I rightly apprehend Admiral Boutakov, he would draw the closest attention to these points. He would have all evolutions commenced by a movement of the helm only, until the ships were in such a position that, by assuming parallel courses and varying the speed, they may either complete the manœuvre, or place themselves in such an order as may require the helm only to do so.

The methods of changing position by means of either helm or speed alone, may be termed *simple movements*, whilst those requiring the employment of both powers may be termed *compound movements;* and it is obvious that, generally speaking, if a change of position can be effected by a simple movement it should be used in preference to a compound one, even at a sacrifice of some delay; for increased celerity of movement is dearly purchased at increased risk of confusion.

Examples of simple movements by variations of helm are given in the changes from K L to A B, to M N, or to O P; and by variation of speed in the change from M N to R N, and from O P to O Q (fig. 3, Plate III), whilst examples of compound movements are given in the changes from K L to R N or I J, or to any of the positions south of the original one except O P and S T.

From the laws governing the turning powers of ships it is evident that variations of speed can only be used when proceeding on a straight course; if the speed be increased or reduced during the process of turning, the ship will find herself out of position on completion of the manœuvre.

Compound movements may therefore usually be divided into two or more simple ones, and the conclusion of each of these may be made use of to rectify inaccuracies, and to restore order before passing to the next. The position M N for instance is one of these "points of rectification" as we might call them for lack of a shorter term. The line K L having its course and direction west, proceeds by a simultaneous movement to change the course to N.N.E., retaining its direction at west as before. On the accuracy with which this formation is taken up, depends the correctness of the remainder of the evolution.

The line should therefore be "dressed" in that position before any further change is undertaken. In the lines R N, O P, O Q, and S T, we have other instances of the same thing, where the ships may continue as long as necessary to preserve the same course and direction without interfering with the ultimate success of the manœuvre.

There are some compound movements which have found advocates on account of their supposed celerity in which these points of rectification do not exist; so that in the performance, each ship makes an entirely independent series of movements, and cannot perceive any errors with reference to the other ships, until the movement is complete. The opportunity for disorder is therefore, so much the greater, unless some special means be supplied whereby each ship's course is distinctly traced out and marked in terms of the only fixed points or lines available, namely, the spaces travelled over in the passage of the ship's head from point to point of the compass.

Examples of this kind are given in the change from K L to C D (fig. 3) and in figures 4 and 5 (Plate II), all of which are quoted from different authorities. Now Admiral Boutakov has shown very clearly that the course to be pursued by every ship in a case of this nature can be strictly ruled in the terms just mentioned, by what he calls his system of "co-ordinates." The first ship in figure 5 for instance, will describe the starboard co-ordinate of 73°, that is, she will port her helm till her head comes N. 73° E., she will then shift it till she regains her former course and steer due north to her proper bearing from the centre ship. The second ship will describe the starboard co-ordinate of 50°, and the fourth and fifth ships will perform the same evolutions to port. But although these rules are capable of strict application, it is sufficiently obvious that there must be great special advantages to justify the use of an evolution so completely disintegrating a column during its performance.

In the diagram (fig. 3) I have endeavoured to give at one view the most important elementary movements of which a column is capable. And for the purpose of comparison, I select a single change of course and direction from W. to N.W., which clearly embraces the principles of all other movements. By the term "direction" I mean the bearing of the leader of the column from the other ships, and in the diagram this *direction* is placed above, while the *course* is placed under the line at the van or rear of each position.

In discriminating between the relative values of any movements, our attention should be first directed to the position held by the new formation with reference to the old. In the cases before us, the change from K L to A B is evidently the simplest; nor when tested as to speed does it contrast badly with others. At a speed of 8 knots, the change will be completed in 7 minutes, whilst there is no other movement, except that from K L to C D, which is complete in less time. This is the simple alteration of course "in succession" the most familiar of all tactical movements.

The next method to be considered is the change of course and direction on the rear to starboard, or on the van to port (fig. 3, Plate III, and fig. 6, Plate IV), for the movements are precisely the same as to

simplicity and duration. In these cases, we have, first a simple movement by the use of the helm only, then a simple movement by variation of speed, and lastly a simple movement by the helm. When the movement is on the rear the ships turn together 8 points plus half the number of points between the old and new direction, as at M N. They then proceed on that course until a new line is formed on the new direction, but with their heads as before, which is shown at R N, this last line being correctly formed, they turn together 8 points minus half the number of points between the old and new course, and the evolution is complete as at I J. If this movement takes place on the van, as represented in fig. 6, the only difference is that the shorter arc comes first and the longer last in the simultaneous movements, and the new line is formed nearly in the position G H.

The next change is from K L to E F, fig 3. The ships all turn to a course perpendicular to the new direction, proceed on that course until they arrive in line abreast, and then turn together to the new course. The evil of this proceeding is shown in the decrease of distance between the ships in the new line, and this decrease becomes more serious, the greater the change of direction. The last method to be considered is the change from K L to G H, and which I have added merely as a suggestion derived from the theory for calculating the circles of ships. I have, with Admiral Boutakov, supposed it possible to mark the helm angle of each ship so as to give them a uniform radius of evolution. I now suppose it possible to mark the tell-tale so as to give the power of turning on any radius measured by cables' lengths. A ship, for instance, which turned on a 2-cable radius at 20°, would turn on a 4-cable radius at 9°, and on a 6-cable radius at 6°, and so on. A line composed of ships so arranged would for *any* change of direction on the van or rear, turn together 8 points so as to form line abreast. The pivot ship then puts her helm to the proper angle for a 2-cable radius, the next to the 4-cable, the next to the 6-cable mark, and so on. They would then steam on till they came into line abreast on the new direction, and turn together to the new course. It should be stated that this method seems to be proposed in the authorized Signal Book, but the only directions given are for the ships "to get into their stations as fast as they can." If the means I propose are practical, to which I hardly pledge myself, the nature of the movement would be simplified. For as the times of turning have been shown to vary as the *cosines* of the helm angles, there would not be a great deal of difference in the time of arriving in line abreast, and the ships' courses would never near each other as they do in other methods.

Now, in all the methods which are given in the diagram, there are, as we see, great differences in the position of the new lines, and there are also great differences in the times of performance, owing to the different spaces over which any one ship has to pass. The relative values of these quantities all vary according to the angle included between the old and the new direction. Those who desire to inquire fully into these differences—and no efficient system can be formed without a full inquiry—will find them clearly set out in Admiral

Boutakov's book. Here, time will only allow me to point out that as regards *position*, the place of the new line cannot vary in a direction perpendicular to its own, more than twice its length, whilst in a direction parallel to its own, its possible variation is only the length of the line, no matter which of these means is used to effect the change.

As regards time, the duration of the change "in succession" is always equal to the time required to pass through the length of the line and the arc between the old and new directions. Whilst in the movement on the van or rear it is equal to the time required to pass over an arc of 16 points plus twice the sine of half the angle between the old and new direction, when the radius is equal to the length of the line. The time occupied in this method, therefore, increases much more rapidly in proportion to the greatness of the change of direction than in that of the simple alteration of course in succession; so that, when time is an object, and the change of direction is small, the simple method is preferable on all grounds except position. Respecting this point, we must suppose that the line G H, formed by a movement on the van, can only take up such a position with the view of passing ahead on a line parallel to A B. This position, however, would be equally gained, were the line K L to proceed on its course until the leading ship is ahead of the position G H, and *then* alter course in succession to N.W. thus performing the evolution in a simple manner, and in a shorter time. Whether the movement be one of advance, the cause of it being to the westward of the original line, or of retreat, the cause of it being to the eastward, it seems probable the change of course and direction on the van has not counterbalancing advantages to make up for its want of simplicity.

In the case of the change of direction on the rear, the matter is different. The position to be occupied by the line I J in its onward course can be attained by two other means. Either by a successive inversion of the line to an East course and afterwards to a N.W. course, or—which is really the same evolution—by every ship following in the wake of M throughout its movements. The change of position is essentially one of retreat; but in the movement on the rear as given, every ship commences the retreat immediately, whilst in the last two cases the rear ship does not make any retiring movement until she has advanced as far as the head of the original line. Besides this the shortest time in which the line can be changed from K L to I J, or any position ahead of it, is by the movement on the rear.

These are important considerations; for if the tactitian's business is to produce necessary results by the speediest and simplest means, every evolution he can put aside as valueless, is so much clearing of the ground before him. Means have been proposed for a change of course and direction on the centre as shown in figure 4 (Plate II). This has received condemnation at the hands of Sir Howard Douglas, and I own that the complication of the manœuvre appears to far outweigh its supposed merits.

If the change required be one of direction only, the course remaining as it was originally, it may either be produced by changing the course

and direction both, and then returning to the old course by a simultaneous movement, which is the preferable method; or else it may be managed by the method of co-ordinates, as in fig. 5, but upon the van instead of the centre.

Before leaving the consideration of the movements of a single column, I should point out that if the line be inverted *together* before the change of direction takes place, and a movement be made upon the then van, the line will be nearly in the position of that now formed upon the rear. If the change be made by an alteration of course in succession, the position will be the same, but the reverse leader will become the leader, and so on. It is also to be observed that the movement on the rear can be equally well made under sail as under steam, when the wind is anywhere between S.S.W. and E. The others can be made with the wind between N.N.E. and E.S.E.

We must now pass on to a rapid application of the foregoing considerations, to those forms and orders of sailing in which it has been proposed to manœuvre a modern fleet. These orders are seven in number, namely, one, two, three, or six columns in line ahead, as in figs. 3 and 6, &c. One, or more divisions in angular formation (figs. 8, 9, and 11, Plate V); one division in indented order (figs. 10 and 12), and an order in groups or knots.

The mobility of a single column we have already treated; that of three and six columns clearly involves only a repetition of the principles exercised in the movements of two columns; whilst the order in "pelotons" or knots—of French invention—does not appear worthy of occupying our time. There remain therefore the orders in two columns, in angular formation, and in "indented order," to be disposed of. "Except while evolutions are in progress or pending," says a great authority, "columns should be in lines ahead. Of all formations, the one most easy for ships in a scattered state to assume is the line or lines ahead; when assumed, it is more easily maintained than any other, especially at night or in thick weather." The change of course and direction is therefore with two columns, as with one, the primary evolution. Fig. 6, Plate IV, points out how, by one small preliminary movement, this change is made as easily by any of the methods given in fig. 3, Plate III, as with one column; that is, when the change of direction is less than a right angle. The two columns being in the first instance a regulated distance apart, with their heads upon a line perpendicular to the *direction*, which in this case is *west*, are required to change that course and direction to N.W., preserving the relations of the columns to each other. The pivot column should reduce its speed, until the head of the wheeling column has drawn ahead *half the number of points* in the change of direction. Both columns may then perform the selected evolutions simultaneously; at the conclusion of which, the wheeling column will be at the proper distance from the pivot column, but astern. It will only be necessary for the pivot column again to reduce speed, to allow the other to arrive abreast of it. It seems here the proper place to point out that a decrease of speed is always at command, whilst an increase is not so;

to ensure accuracy of movement therefore, a certain maximum speed should be established, and varied only in reduction.

If the change of direction in two columns is greater than 8 points, it is evident the wheeling column, if not very close to the pivot, must pass over a very great space to preserve its position on the original side of the pivot column. In such a case it seems decidedly preferable to wheel the formation by columns. The movement is precisely the same, except that the port column now becomes the pivot, and reduces speed, so as to allow the starboard column to draw ahead half the number of points before commencing the evolution. When re-formed on the new direction, it is found the columns have changed sides, and what was the port column has now become the starboard. Here we must advert to a most important consideration, namely, whether it is necessary for the mobility of a modern fleet in columns to prescribe the sides *permanently* on which divisions shall lie. If, for instance, a fleet is in two divisions, numbered first and second, does any necessity exist that the second division should be *always* on the port side of the first? Whether, in short, in Sir Howard Douglas words, there is an objection to "clubbing a fleet?" When ships fought under sail, the weather position was the all-important one. The Admiral almost invariably held it, heading the weather division, and thus ready for any emergency. Fleets cruising, obviously spent most of their time on a wind, and this weather position once taken up was by the simplest of all possible movements perpetually retained. How is it now? Can any one declare that the starboard side is intrinsically more important than the port? more commanding, or more open to attack? Can the starboard position be maintained in a steam fleet by the simplest movements? If not, what remains as the only reason for maintaining that which is the foundation of our present evolutionary code? It is that "fogs, gales, detached duties, and leaving harbour, frequently cause fleets to be dispersed. When 'rejoining' or 'closing' ships have ascertained the position and course of the flag ship, they should as a consequence, know where to form with relation to her. . . . . Even in daylight, signalling is often inconvenient; but at night it is only in fine weather that signals can be distinguished, and they should not be required to indicate a ship's established station." This was written before the flashing system of night signals had taken the important position it has now attained. Those who have seen it in use in fleets, know as a certainty, that no argument can now be founded upon the difficulty of signalling at night, as it no longer exists. With regard to the remainder of the statement, I would say, are we justified in retaining an element of confusion permanently, for the sake of avoiding it in special cases? Our authorized system of tactics is based entirely upon the presumed necessity for thus prescribing permanently the position of divisions of a fleet. Sir Howard Douglas, reasoning from the analogy of military movements, does not believe in this necessity, and I very humbly following him, cannot but perceive that a great deal of complication is avoided, if the Admiral is left perfectly free to place the divisions of the fleet where most convenient for the time being. Nevertheless,

great and experienced tacticians are on the other side, and we must not forget that. (I have dwelt upon this because it is quite a fundamental principle in modern naval tactics).

The distance apart of columns should clearly be regulated by their length, and not arbitrarily fixed as at present. Probably if it were *equal* to their length it would be found convenient.

We now come to the angular formation of Sir Howard Douglas, given in figs. 8, 9 and 11, and which has found a place in all systems of tactics. With this formation, unless the course corresponds with the direction of one wing, as at B, fig. 11, we have a double line-of-bearing to preserve, respecting which lines, an authority I have often quoted says, "they require two adjustments, one of distance and another of direction, independent of the course; and close as adjacent ships should be to each other, it is obvious that a large deviation from a bearing will speedily be produced by a difference between their rates. Such a disturbance in a few instances would obliterate any trace of a formation. . . . ." At the very outset, therefore, we get a strong objection to the formation, which, if valid, would prevent its being used in the everyday movement of a fleet, which again is absolutely fatal to its use against an enemy. For what Admiral will be rash enough to attempt to maintain an order in the face of an enemy which he finds too complicated to form his fleet on under ordinary circumstances? Of course Cornwallis' retreat will occur to my naval hearers as a direct contradiction to this view. But I am afraid we have decided too superficially, in admitting the belief that Cornwallis placed his five ships in any particular form. Ekins, for instance, in his first edition, gives two totally different forms—one of them certainly an angular formation, but with the point turned *from*, instead of towards the enemy. He confesses this is incorrect, and gives another totally different plate, which James asserts is equally incorrect. Brenton assumes the wedge form, but I believe does not make out his case by any special reasoning.

Besides the difficulties alleged to exist against the maintenance of such a formation, the gravest defects are discovered when we apply the test of changing course and direction while preserving the form. Figures 8 and 9 are attempts to show how this may be most speedily managed. In fig. 8, the movement is pivoted on the starboard wing, and in fig. 9 on the angular point, and it will be immediately seen that both of them involve such variety of movement, that nothing short of constant practice could prevent confusion.

In neither method is that form of compound movement without points of rectification—to which I previously objected—avoided. The change, in fact, can only be effected by the use of Admiral Boutakov's co-ordinates, and if English naval officers object to their use, they must, in consistency, object to formations whose mobilization can only be attained by employing them.

The last formation to which we may apply the test of mobility, is the French "indented order." This, as may be seen from the diagram fig. 10, is simply the order in two columns with their distance apart decreased, and with the ships of one column abreast of the intervals in

the other. The mobility of such a formation is precisely that of two columns, but with the times and spaces required for any evolution considerably reduced. This is at once perceived from the diagram figure 10.

Now the order in two columns, is that which has been found since ever we have had a navy, the one most suited to a cruising fleet, and in our greatest naval victory it was that selected for attack with no less than 27 sail. Is it likely that with the evident tendency towards reduction of numbers, and increase of individual efficiency in our fleet, we shall ever see a larger fleet acting in concert than Nelson had at Trafalgar? Would not a larger fleet be practically out of control? If this be so, as far as mobility is concerned, we might well content ourselves with the order of sailing in two columns; and the simple approach of these columns to each other under steam, would without altering the every day process of manœuvring, give us the "order indented," recommended by the French as an efficient fighting order.

After we have selected the form or forms in which we propose to place our fleets, the changes of form or position necessary, and the manner in which these changes are to be made, we have still a most important element of mobility to arrange, namely, the mode in which simultaneous action is to be secured: the process of transmitting the orders of the commander of the fleet, and the nature of those orders.

If a General on land were restricted as an Admiral is at sea—to the use of signals for the conveyance of his orders—what position would he assume in manœuvring his troops? He would place himself where he could best see and be seen. We in the Navy say practically that these are secondary matters. The Admiral's main duty is to set an example of personal bravery and lead in—or at any rate place himself in the "fore-front of the battle"—the centre of his line.

Why was it that in olden times, with sailing fleets, the Admiral invariably took part, and usually a foremost part in the combat, acting so differently from his brother-in-arms on shore? Simply this, that if he did not do so, there was no other occupation left him. Movement, or at any rate, combined movement was not possible very soon after the fleets joined battle. The firing brought the wind down, their masts were shot away, and the ships lay deprived of any power to obey orders, had such reached them. But we in modern times have forgotten these things, and we have spoken as if the presence of their Admiral under a hot fire were necessary as an animating spectacle to stir up the courage of his followers!

Thus, then, the Admiral's functions as a commander of a fleet in old times, ceased with the commencement of the action. The fleet became disintegrated, and fought out its victory in a succession of single combats. Have we reason to believe that what has been, will be, in this case? or are we not rather to adopt the view of our gallant late opponent in command of the "Vladimir," and say that steam will "effect in naval tactics a revolution analagous to that which took place in military tactics at the end of last century." That "we *should* and we *can* demand from steam ships, formations and evolutions as sudden as they are unexpected?"

If we look at the only decisive naval combat ever fought in the open sea under steam—that between the "Alabama" and the "Kearsage," the one great element which was present there, but absent in all former actions, was rapid motion. Will not this element extend to fleets? It is from these facts I take the view that in future actions the Commander-in-Chief will not take a position in the line. He will place himself in some swift, quick-turning vessel, not unarmed nor unplated, but still a light ship—the flag ship of the future—where he can best view the movements of his own and the enemy's fleet, and where his signals can be at once perceived from all quarters. Such, as I look upon it, is the first requisite for giving prompt effect to the combinations formed in the Admiral's mind.

The next point tō be studied is the language in which the orders directing movements should be conveyed. These orders should be terse, short, unambiguous, and should not require reflection on the part of the recipients before carrying them out; they require a basis, therefore, of the clearest definitions, and their number must be very considerable to include the various attitudes in which a fleet may be found.

Our Evolutionary Code, the General Signal Book, is the growth of centuries; by little and little have alterations been made in it as the wants of a fleet became more and more understood. After the long naval wars, this book remained to us as the combined wisdom of our warrior forefathers. How could their successors presume to alter arrangements so sacred? But, on the other hand, steam pressed more and more into the van of determined facts. How to leave all the work of the founders of our great name untouched, and still make provision for the new and increasing wants? Such was the problem set before those at whose hands the book was to obtain remodelling; and who, therefore, hesitatingly endeavoured to avoid destroying the old formulæ, whilst adding those required in the new circumstances of the navy. The result of this is but the natural one. Our Evolutionary Code is on all hands allowed to be unfinished, defective, and ambiguous. I propose now to give two instances of the action of these ambiguities, which recently occurred under my own observation, as they point out not only the sources of error but their remedy.

A squadron of eight ships (fig. 13, Plate I) was lying at anchor, with their heads south, in two colums north and south. The exit from the roadstead was to the southward, and the wind was abeam. The columns were in inverted order; that is, the headmost ships in order of sailing were now the sternmost, by reason of the direction of the tide.

The officer in command, wishing to weigh under steam, and intending that the real leaders of the columns (Nos. 1 and 5) should weigh first, and the others in succession (2 and 6, 3 and 7, &c.) made a signal to the following effect:—"The headmost ships in each column to weigh first, the rest in succession;" this being the only general signal possible under the circumstances. The result was that Nos. 4 and 8 ships at once prepared to weigh, and No. 8 actually did so, thus leading both to confusion and delay in the departure of the squadron. The error arose simply from the fact of the term "headmost ship of a

column" being altogether undefined in the Signal Book. Officers are left in doubt as to whether the term is to be permanently applied to the regulated leaders of divisions when in sailing order, or to those ships which happen to be ahead at the time the signal is made.

The second case I have to adduce involves an ambiguity common to a great number of our evolutionary signals, and as serious as it is common.

The situation is given in fig. 14. The ships, still eight in number, were in line of battle under steam and sail on the port tack, wind just free, the starboard division leading. It was intended to form the order of sailing in two columns, the port column forming on the starboard side of the starboard or leading column, in the position at A.

There was in this case a choice of three signals to express the Admiral's wishes, The first said, "form the second order of sailing under steam," with a note of reference to a plate which is reproduced in fig. 15. The second was, "form the prescribed order of sailing in two columns," with a note of reference to the same plate. If the first of these signals had been made, the port column must immediately have taken its port position with reference to the other column, *not* what the Admiral wanted. If the second signal had been used, Captains must have debated, first, whether the ships were considered under steam or sail. If they decided under steam, and had acted on it, they would have gone wrong, as we have seen. If they decided under sail, they had then to consider whether they were supposed on a wind or "large." If they had decided for "on a wind," they would have gone to leeward, and right, if otherwise, to windward and wrong. The third and last signal at the Admiral's disposal, which was the one used, gives the order, "form the order of sailing in two columns;" with a note stating that "when divisional flags accompany this signal, the upper flag will point out the weather column, if sailing on a wind; and the starboard column if sailing large or before the wind, or under steam." Here we had precisely the same confusion as in the other cases. Who was to decide whether the ships were under steam or sail, when they were under both, or "large" or "on a wind," when it was doubtful? The result of the proceeding was, however, that the port column went the port side of the Admiral, exactly where he did not want it.

We have seen, in these two cases, the gravest mistakes made, from a want of clearness in the expressions intended to produce the simplest combinations. May we not justly suspect that in more complicated as well as more important evolutions, this ambiguity and looseness of wording, if left unimproved, may hereafter lead to very serious consequences.

Besides a want of perspicuity which is very apparent throughout our Evolutionary Code—and which is probably due to the number of hands through which it has passed; it seems apparent that a great deal of the confusion proceeds from the many varieties of movement which most signals are made to include in their signification. Not many orders can be issued which direct one single movement, under all circumstances the same; but we have "*if* so and so is the case," then

If we look at the only decisive naval combat ever fought in the open sea under steam—that between the "Alabama" and the "Kearsage," the one great element which was present there, but absent in all former actions, was rapid motion. Will not this element extend to fleets? It is from these facts I take the view that in future actions the Commander-in-Chief will not take a position in the line. He will place himself in some swift, quick-turning vessel, not unarmed nor unplated, but still a light ship—the flag ship of the future—where he can best view the movements of his own and the enemy's fleet, and where his signals can be at once perceived from all quarters. Such, as I look upon it, is the first requisite for giving prompt effect to the combinations formed in the Admiral's mind.

The next point to be studied is the language in which the orders directing movements should be conveyed. These orders should be terse, short, unambiguous, and should not require reflection on the part of the recipients before carrying them out; they require a basis, therefore, of the clearest definitions, and their number must be very considerable to include the various attitudes in which a fleet may be found.

Our Evolutionary Code, the General Signal Book, is the growth of centuries; by little and little have alterations been made in it as the wants of a fleet became more and more understood. After the long naval wars, this book remained to us as the combined wisdom of our warrior forefathers. How could their successors presume to alter arrangements so sacred? But, on the other hand, steam pressed more and more into the van of determined facts. How to leave all the work of the founders of our great name untouched, and still make provision for the new and increasing wants? Such was the problem set before those at whose hands the book was to obtain remodelling; and who, therefore, hesitatingly endeavoured to avoid destroying the old formulæ, whilst adding those required in the new circumstances of the navy. The result of this is but the natural one. Our Evolutionary Code is on all hands allowed to be unfinished, defective, and ambiguous. I propose now to give two instances of the action of these ambiguities, which recently occurred under my own observation, as they point out not only the sources of error but their remedy.

A squadron of eight ships (fig. 13, Plate I) was lying at anchor, with their heads south, in two colums north and south. The exit from the roadstead was to the southward, and the wind was abeam. The columns were in inverted order; that is, the headmost ships in order of sailing were now the sternmost, by reason of the direction of the tide.

The officer in command, wishing to weigh under steam, and intending that the real leaders of the columns (Nos. 1 and 5) should weigh first, and the others in succession (2 and 6, 3 and 7, &c.) made a signal to the following effect:—"The headmost ships in each column to weigh first, the rest in succession;" this being the only general signal possible under the circumstances. The result was that Nos. 4 and 8 ships at once prepared to weigh, and No. 8 actually did so, thus leading both to confusion and delay in the departure of the squadron. The error arose simply from the fact of the term "headmost ship of a

column" being altogether undefined in the Signal Book. Officers are left in doubt as to whether the term is to be permanently applied to the regulated leaders of divisions when in sailing order, or to those ships which happen to be ahead at the time the signal is made.

The second case I have to adduce involves an ambiguity common to a great number of our evolutionary signals, and as serious as it is common.

The situation is given in fig. 14. The ships, still eight in number, were in line of battle under steam and sail on the port tack, wind just free, the starboard division leading. It was intended to form the order of sailing in two columns, the port column forming on the starboard side of the starboard or leading column, in the position at A.

There was in this case a choice of three signals to express the Admiral's wishes, The first said, "form the second order of sailing under steam," with a note of reference to a plate which is reproduced in fig. 15. The second was, "form the prescribed order of sailing in two columns," with a note of reference to the same plate. If the first of these signals had been made, the port column must immediately have taken its port position with reference to the other column, *not* what the Admiral wanted. If the second signal had been used, Captains must have debated, first, whether the ships were considered under steam or sail. If they decided under steam, and had acted on it, they would have gone wrong, as we have seen. If they decided under sail, they had then to consider whether they were supposed on a wind or "large." If they had decided for "on a wind," they would have gone to leeward, and right, if otherwise, to windward and wrong. The third and last signal at the Admiral's disposal, which was the one used, gives the order, "form the order of sailing in two columns;" with a note stating that "when divisional flags accompany this signal, the upper flag will point out the weather column, if sailing on a wind; and the starboard column if sailing large or before the wind, or under steam." Here we had precisely the same confusion as in the other cases. Who was to decide whether the ships were under steam or sail, when they were under both, or "large" or "on a wind," when it was doubtful? The result of the proceeding was, however, that the port column went the port side of the Admiral, exactly where he did not want it.

We have seen, in these two cases, the gravest mistakes made, from a want of clearness in the expressions intended to produce the simplest combinations. May we not justly suspect that in more complicated as well as more important evolutions, this ambiguity and looseness of wording, if left unimproved, may hereafter lead to very serious consequences.

Besides a want of perspicuity which is very apparent throughout our Evolutionary Code—and which is probably due to the number of hands through which it has passed; it seems apparent that a great deal of the confusion proceeds from the many varieties of movement which most signals are made to include in their signification. Not many orders can be issued which direct one single movement, under all circumstances the same; but we have "*if* so and so is the case," then

such or such modifications are to be made in the original order. This injudicious compression seems to proceed from a desire to reduce the number of evolutionary signals as much as possible. And it is most singular to observe, that it is only amongst the very important signals that this compression is found. All orders relating to Officers, stores, provisions, &c., in the general Signal Book, are clearly expressed, capable of no double meaning, and requiring no reflection to obey them; but when we come to those referring to fleet movements, the enemy, and other important matters, where vital interests are concerned—then only do we meet with the numerous "ifs" and "ors" to which I take exception.

It is quite an axiom in signalling, that speed cannot be gained at the expense of certainty, so that you cannot convey an order in ambiguous terms without causing delay as well as confusion. To increase the mobility of a fleet, therefore, a very large increase in the number of evolutionary signals is required, each expressing a direct and clear order. A large choice in the Signal Book means a small number of signals to produce any given effect. It is for the Admiral to reflect and choose his distinct orders and for his Captains to act on them with that promptitude and decision which cannot follow a vague command. The first requisite in definite orders are definite terms, As we stand, we have redundancy without definitiveness. A "line ahead" for instance has four other different names;—a division, a squadron, a column, and a line of battle. Here again there are some terms *expressive of position*, which are retained by portions of the fleet when those positions are not held; there are others which may or may not change—it is not known which. If a fleet is divided into *two* parts they are called divisions, and have two special flags to distinguish them, if into three parts they are called *squadrons*, and have three other different flags to distinguish them. Many of my hearers will say, "these are mere details, why trouble us with them?" My answer is, that on these very details, hangs the amount of success to be obtained by our fleet in a future naval war. I am in great fear, when I think of the approach of an English fleet towards an enemy, and of the effect upon the Admiral's mind of the alarming discovery, that his fleet is not in hand—that his orders are misinterpreted, and his fleet in hesitating doubt.

And yet the principles on which the remedy for all these things may be founded, are not difficult of discovery, we only want sufficient boldness to perceive that a great change has come over our Navy, requiring a great reform to meet it. And that could the spirits of our naval heroes animate us, we should quickly shake off the trammels of tradition, the most dangerous shackles in matters of science, as they are the firmest safeguards in matters of politics.

What then are these principles? First a selection of terms inexpressive of position and unchangeable. As for instance, in a fleet divided into two parts they would be termed the *First* and *Second Divisions*, if in three parts, the *First*, *Second*, and *Third Divisions*, so the established headmost ship of a column might be called its "*Leader*," the established sternmost ship its "*Reverse Leader*."

Then we want a selection of terms, exclusively referring to position, van, rear, centre, port, and starboard, only applying to the part of the fleet which holds such position at the moment.

Framing all orders on these terms and using no others, and not stinting ourselves as to the number, so that we secure the distinctness of the commands, we may rest assured that so far as the meaning of words goes, we shall have gained our point.

Such simple orders as I have shown to be defective under present arrangements would then stand thus: for fig. 13 (Plate I) the order would be, "Weigh, leaders first, the rest in succession, reverse leaders last." In fig. 14 it would be, "Form the second order, the second division forming to starboard."

But few other points require notice ere we conclude the whole question of the mobilization of fleets. In the arrangement of the symbols conveying orders, it should be remembered that evolutionary signals are the most urgent of all, requiring the promptest attention. It is a well understood principle that the most urgent signals should be composed of the smallest number of symbols; and, therefore, the practice which now exists of using additional flags to modify the meaning of evolutionary signals, should, if possible, be abolished.

The free use of diagrams in the Signal Book is of the greatest value, and their number might be advantageously increased. They should, however, not be of the arbitrary and unsystematic character which they now are, but should be drawn to scale, with the approximate courses and positions of the ships marked on them.

Such then appears to me a faint outline of the various principles and requirements called forth by the necessity of securing the mobilization of a modern fleet.

Some of our most distinguished Admirals have pointed out the advantages of increased communication by signal between ships in a manœuvring fleet; and it is undoubtedly the case, that in time of action some additional mode of communicating intelligence or orders, besides the flags, would be an advantage. I hope that so soon as our improved night signals are completely established, we shall find their principles fully applicable to the supply of this want by day.

We have now, before concluding, to give one rapid glance at the future of "*naval strategy.*"

If we take a general survey of the nature and progress of naval weapons, we observe that on all sides we are increasing the defensive, or resisting powers of ships, whilst we are at the same time bringing up the powers of our artillery to something like a level with them. We may, or may not, therefore, be decreasing the effective range of naval guns—we do not know this yet. We do know, however, that we can only keep up or extend this effective range at the expense of a great reduction in the *number* of the guns used. What does this reduction in the number of guns mean? It means less smoke and therefore less confusion in future naval actions. It means also fewer shots at an enemy in any given time. It means that an antagonist cares less about raking fire, and may come to close quarters comparatively unharmed. If, having arrived at these conclusions, we

take another survey, we see a new weapon, or rather the revival of an old one, steadily advocated for years by Sir G. Sartorius, springing into favour in all directions. Nearly all war ships are being fitted for the destruction of opponents by means of a beak, or armed stem. At the very time, therefore, that this new weapon is becoming recognized as efficient, we are actually driven by the force of circumstances to prepare the way for its use by the reduction in the number of our guns! What effect the universal adoption of this weapon will have upon future naval duels in the open sea, it may be difficult to say, but its effect on the battle formations of a fleet is perhaps easier to surmise.

Let me, however, exclude the idea of the ram for a few moments, while considering the relative strength of a few formations, under artillery fire only.

Not to confuse ourselves with new forms, let us take those orders of battle already proposed, which are but three in number, namely, the simple single column, the angular formation, and the French indented line.

Sir Howard Douglas, perceiving the inherent weakness of the extended line of battle, made apparent in numberless actions, but nowhere so strongly as at the Battle of the Nile, and understanding that though no other formation was possible with fleets whose only motive power was the wind, many other more desirable formations might be maintained under steam, proposed to apply the well-known principles of fortification to ascertain the formation most proper to be employed for the mutual support of the ships composing a fleet. He argued, that if ships were placed so that the broadside fire of one might be crossed by the bow or stern fire of another, the strength of the formation would be proportionately increased. Sir Howard wrote when the line-of-battle ship was in favour, and calculated on a bow and stern fire of from 7 to 9 guns, and though at present the proportionate power of the bow and stern, as compared with the broadside, appears less than it was, it may probably recover itself in the reduction of the number of guns with which we are threatened.

The scope of the General's views may be understood from fig. 16 (Plate VI) which represents a portion of the line of battle, and fig. 17, which is a portion of Sir Howard's proposed order. If we suppose the ships in fig. 16 to be attacked by two others steering the same course, they may clearly place themselves at A and B abeam of the rearmost ship without receiving a greater fire than a half broadside from their immediate antagonist, and half the stern fire of her next ahead. The attacking ships must forge ahead considerably to experience the broadside fire of the headmost ship, and when they do so, they at once begin to feel less of the broadside fire of the rear ship. If, however, the same attack be made upon the rear ship in fig. 17, as at C and D, the ship D will experience not only the half broadside of her antagonist, but the whole of the stern fire of the next ahead, while the ship C will certainly receive a portion, and, if she forges ahead a little, the whole of the leading ship's broadside, in addition to the half broadside of the rear ship. It seems to be in these points that

the weakness of one formation and the strength of the other consists, and such strength or weakness evidently remains to them in advance, retreat, or in simple resistance. Of course, I am called upon, not to omit the probability of the presence of turret ships in fleets from my surmises; their presence would doubtless have an important effect on formation, supposing a whole fleet composed of them, but we need not imagine they would *reverse* the elements of strength in comparing any two formations, although they might, from the larger arc covered by their broadside fire, bring up the strength of all formations to a closer level.

Before proceeding I might remark that, if I gather Sir Howard Douglas' views correctly, he does not put forward the angular formation, or double echellon, so much as an order of battle, as an order of sailing, one of great strength, in which fleets should permanently sail, ready to repel or advance to an attack as they stand, and as a convenient position preparatory to forming a *single line of bearing*, which seems his ideal of an actual battle order. I cannot shake off the conviction that the great artillery General was not, in his proposals, fully alive to the fact that a formation, to be preserved, *must* progress. A single line of bearing must therefore be perpetually either nearing or separating from the enemy, and could not be maintained as a formation of simple resistance, in which point it therefore is objectionable.

Reverting, now, to the diagram. If we take three ships into consideration, and place them as at E. (fig. 18), we have the line of battle, if, as at F, we have the angular formation continued. In this diagram, the ships are 300 feet long, 250 yards apart from centre to centre, and engaging at a distance between the centre ships of 200 yards; to allow for possibilities, I suppose that the broadside fire covers an arc of 6 points of the compass from each ship. Considering the two formations separately, we observe that whilst three ships may so place themselves upon the rear or headmost ship of the line of battle, and receive no heavier fire than when the third ship was absent, in the angular formation it is not possible to maintain the fire of three broadsides upon any one of the ships, without receiving generally part of another ship's broadside, and certainly the bow or stern fire of two ships, besides the fire of the ship they are attacking.

Considering now the two formations as opposed to one another, we see first that the base of the angular formation is less than the length of the line of battle, therefore its fire is more concentrated. The broadside fire of the base ships is in fact available upon the centre ship of the line of battle, whilst none of the broadside fire of the van and rear ships of the line can be directed upon the centre ship of the angular formation. But this superior concentration is gained in a much looser order; for though the angular ship is distant from the wings but 250 yards, the same as the interval in the line of battle, these wing ships are distant 350 yards from one another. We may suppose, therefore, that order can be more easily maintained amongst three ships so placed, than when placed in the corresponding line of battle.

But this formation, besides representing the three angular ships given at A, fig. 11, Plate V, also represents the three ships of the French indented order, given at D, fig. 12.

If now we add two more ships to these three, we may use them to extend the complicated lines of bearing, where we obtain Sir Howard Douglas' formation, A, or to extend the simple lines ahead, when we obtain the French indented order, D, fig. 12. In both these orders, the principles of mutual support are rigidly carried out, and carried out in a manner which leaves small choice between them. The *length* of the formation is the same in both cases, and though in the angular figure, concentration of the whole broadside fire takes place at 400 yards due north of the angular ship, whilst in the indented line it does not take place within 600 yards, yet on coming within these distances, the wing ships in the angular formation cease to act at all, whilst the extreme ships in the indented line still exercise their bow and stern fire. In such brief examination as we are here able to give, there does not appear to be much difference in strength, as to broadside attack by artillery, between the indented and the angular formations, so long as the angular point is directed towards the enemy. If, however, this is not the case, the formation becomes weaker and weaker, until, should the attack be parallel to one wing—as, for instance, from the north upon B, fig. 11, nearly half the power of the fleet is lost, and the formation becomes in that respect worse than the line of battle.

In advancing to attack, the angular formation will be in the positions given in figs. 8 and 9, and the indented form, as at C, fig. 12. And in this form also, the advantages of bow fire appear pretty equally balanced. It seems, on the whole, that the question between the angular and indented orders becomes entirely one of mobility. So far as I can see these advantages lie on the side of the latter; but as I have, since my views were formed, been kindly shown by Admiral Boutakov some simpler methods of moving the angular formation, I should state my want of perfect conviction upon the matter.

It is right also to state, that Sir. H. Douglas distinctly condemns the "indented order," apparently for the reasons which to my mind constitute its merits—the looseness of its order relative to the concentration of its fire.

But in order to set aside any lingering affection we may retain for the old *line-of-Battle* as a fighting order; let us just recall the fact, that the serious part of a future naval attack does not appear to be the guns—but the rams. How will they affect the question?

If we look into the history of all our naval actions, the decisive victories were gained, only when we succeeded in breaking through the enemy's line. The closest possible line of battle was the safest possible position, and an opening therein was hailed with joy by the attacking party as an earnest of success. If there were no opening, it was all but hopeless trying to make one:—as to a ship making sail, and running straight at any ship in the line it would have damaged both combatants equally—and was not put in force, the most that was done was to try and squeeze through an interval.

But suppose an Admiral in command of a steam fleet, some ships of

which are rams, can we not well imagine his exulting in the certainty of victory the moment he saw a close line of battle neatly drawn up in the most convenient position possible for the action of the new and terrible weapon? The enemy could never be so foolhardy as to attempt such a proceeding; the approach of the rams would surely break up the line, for no Captain would allow himself to be fairly run into when he could avoid it, and thus the great aim and end of all our great naval leaders would be obtained before even the action commenced. I cannot believe we shall ever see the line of battle again for these reasons; but instead, we want some form sufficiently loose to allow individual ships, by reducing or increasing speed, to avoid the blow of a ram, without disturbing the general order. Such a formation we appear to possess in the indented order. In the closest order, such as we have been considering, every ship has 350 yards, astern and ahead of her in which she can move, without disturbing the other ships, and this, judiciously used, should be sufficient to avoid the stroke of the ram; suppose one of these approaches from the north the centre ship in D fig. 12, with the intention of striking her, *she* may pass either ahead or astern to let the ram go through, but it will be the business of the ship on her quarter to reduce speed for a moment, and as the ram passes through, supposed to have missed her object, to charge at her full speed, when she can hardly fail to inflict at least some damage in return for the permission to pass. Where a formation is so loose as that of the indented line, it *must* be difficult to break it, and we may expect that many rams might pass ere the gap was wide enough to admit an enemy's fleet between.

As a defence against rams, would not the knowledge that every ship in an indented line had a torpedo extended from her bows, which required only a gentle *rub* to call it into action, be a wholesome disturber of the nerves of any adventurous ram-captain who might be disposed to try the new weapon?

Such, then, is my very rude and faltering attempt to evolve some order out of the chaos in which the science of Naval Tactics, by the tremendous material changes in all Navies, has been left. I have doubtless put forward many faulty views—naturally such are to be expected from comparatively inexperienced men like myself. I have spoken, however, with a freedom which some will condemn as the natural concomitant of such inexperience; but I shall find fault with no one who in thus condemning me, will at the same time add to the weight of his experience, the labour I have given to arrive at definite views.

I have spoken of the existing tactical arrangements in our own Navy in strong terms, because I have for many years *felt* strongly. But it is a very different thing to find fault with the deficiencies of a system, and to say that the system is blameably deficient. It is hardly ten years since the main body of our fleet were sailing ships, and so long as there were any sailing ships in the line of battle, the time for a great change had not arrived. Our Evolutionary Code is yet in its transition state, and I remark upon it, that the fact may be

appreciated, and that if the time has come now for a decided change, we may set about it with some idea of the work before us.

I must, before closing, express publicly my sense of the kindness of Vice-Admiral Sir Wm. Martin in placing his most valuable labours at my disposal, to Admiral Boutakov, and to those other professional friends who kindly supplied me with the hints and the data forming the groundwork of my paper.

I have only to say, finally, that no one can be more conscious of the weakness of my attempt than I am myself. I can but hope, for their own sakes, that my indulgent audience have not shared in my dissatisfaction with my work.

The CHAIRMAN: As Admiral Boutakov, to whom we are so much indebted, has kindly honoured us with his presence, I am sure we shall all be glad to hear some remarks from that distinguished officer.

Admiral BOUTAKOV: It would be very difficult for me, knowing very little of the English language, to make any remarks. I can only say that it is a great pleasure to me to have my name mentioned in such a distinguished Society.

The CHAIRMAN: I hope some Officers present will make remarks. The subject is very important, and it has been very distinctly and clearly set before us. Perhaps Captain Selwyn will offer some observations.

Captain SELWYN, R.N.: I do not know why the Chairman calls upon me, unless it be that I made a promise last year that in case no one else would favour us with a better *résumé* of Naval Tactics as they exist, before the time arrived at which I should be able to do it, I should be happy to try my hand at it. But I consider myself quite absolved from the promise, inasmuch as Captain Colomb has so very well fulfilled the task. We owe to him every obligation for having brought under our notice the whole subject, which, I may say, has been almost avoided by naval men, from their feeling the uncertain state in which the question remains, pending the knowledge which we hope to obtain of the powers which we have at our disposal. I confess I listened with some anxiety to hear mention made of the very perfection of that power of which I speak—the application of twin screws. I have only to say that by means of it, a power is given us quite equal, if it is not superior to, that possessed by the infantry soldier. We can "right about face," or perform any other possible evolution required, with the utmost possible certainty and security. I speak strongly on the subject, for I have myself been witness to its effects. Not only can we train guns more quickly than with handspikes or tackles, but we can go straight astern on any point that may be chosen, of the compass. We can turn on our own centre with the most perfect certainty, and in the shortest time; and we can obtain with small vessels a speed which it is fruitless to expect with the same power applied to the single screw. Therefore, I did listen with some hope that Captain Colomb would have adverted to that, which would have been an important part of the question, as it at once sweeps away the whole of the necessity for curves in very many of the evolutions. We can reverse our order; we can perform evolutions which we could not perform with any possibility before; and for avoiding the blow of the ram, or for any other of those sudden evolutions which he has ably pointed out, may be required, it is very evident that the power of turning on the centre is most important. If only for the sake of simplifying the manœuvres which fleets may be expected by some to perform in the future, the twin screw would be a thing into which we ought to look closely, it has also other advantages. But I confess myself to be one of those who doubt very much whether, in the future, there can be any such evolutions of fleets as we have formerly seen. We now have guns to which it would be perfectly fruitless to oppose the best armour-plate we possess at the distance of yard-arm to yard-arm, which was formerly sought by an English Captain. The certain result of a single discharge of a 600-pounder into a vessel's side, pointed downwards, would be to send her to the bottom; she could not avoid it. Nor do I think any vessel can be armoured that will effectually resist such a shot

from a smooth bore, a spherical shot made of hardened steel, at short ranges. We have, partly by the labours of the Officers of the Navy in this Institution, arrived at a definite conclusion in exact accordance with the practice of the Americans in their guns, that there is no rifled gun, no form of rifled gun, which can possibly give the same velocity, and, therefore, can possibly give the same useful result as the smooth-bore, with hardened spherical shot, with a given charge of powder and a given strain on the gun. This being the case, it becomes almost impossible to contemplate with any degree of favour any such arrangements as those which were contemplated of reducing the speed of the "Warrior" of 15 knots down to the speed, say, of the "Enterprise," of 7 knots, in order to preserve an order of battle which would only have the result at last of bringing the ships into a danger which they ought not to seek, and which would ensure the destruction of one, if not of both ships. Now, it is not to be desired that half a million of money should be risked in that way. If you will have ships costing half a million of money—Mr. Scott Russell's fleet of the future—then it is evident we Naval Officers shall have to take the greatest care of them. We shall not be able to feel satisfied if the whole result of a naval action is, that on both sides an equal number of vessels have gone to the bottom. Nor do I think any nation will long entertain the question of naval warfare at all, if such is to be the only result. Sailing in fleets and manœuvring in fleets must lead to such a result. I do believe the experience we have had of the fights between the "Alabama" and "Kearsage," and of other American fights, all point to the question of trial of speed first, and trial of guns second—the speed depending, of course, upon the character of the fuel, to which Captain Colomb adverted—and then on the precision of the gunnery and the particular address of the officers in command. But that we should ever have to depend upon an Admiral's view of the question, when one shot may upset his whole calculations, I do not think is possible. I think when a hostile fleet is seen, it will be chased, and that we cannot afford to wait till the slowest ship comes up, and that they will be caught in the order of their sailing, and that they will then form a series of single combats not under any possible formation. I do not see any possibility of recurring to the old system. I say it would be wise to study all these conditions, and to be even more bold than Captain Colomb, and to throw aside the old formations and the old arrangements of manœuvring under sail. Speaking to that point of being under sail, and the difficulty of knowing whether a vessel is under sail or under steam, I say the Admiral will little understand his business who takes his fleet into action under sail at all. Steam must be the moving power. It gives a certainty which you cannot get under sail; you do away with the great proportion of the embarrassments consequent on the use of sails; and you have to attend only to your engines and not to your yards. Therefore, I do not think, valuable as Captain Colomb's labours have been in bringing the subject before us, that we shall go forward in the direction which he has here indicated in the tactics of the future. Those tactics it is perfectly evident will never be decided until the first battle is fought. I think each individual Captain ought to be enabled to study, much more than he is allowed to do at present, the powers of his ship under steam. The difficulty now is that the economy of the country requires the Captain to be ignorant of his ship's powers. He is not allowed to use steam; he is told to abstain carefully from its use. How, under those circumstances, is he to be satisfied as to the capacity of the ship for what she may be called upon to perform in case of necessity? More latitude must be given, and that that may be done we must have, if possible, a cheaper fuel. To that point I am now turning my attention, as my brother Naval Officers are aware, and I hope shortly to lay before them more important information than I have yet been able to obtain upon the subject.

Captain LEOPOLD HEATH, R.N., C.B.: It is, perhaps, right, when one hears a heresy published in this lecture room, to say one word to refute it. Captain Selwyn compares smooth bores with rifled guns, and says under no circumstances will equal velocity be got out of rifled guns with equal charges of powder. I think I read a letter from our Chairman in "The Times," refuting that, by giving the velocities of some experimental guns, and comparing them with these very smooth bores.

Captain COLOMB: I should say that I specially avoided the subject of twin screws

as being one upon which it is extremely difficult to get any data; besides, had I entered into that question, it would have opened up so much ground that, instead of occupying your time for an hour and twenty minutes, I should have occupied it for four or five hours, which would not, perhaps, have been satisfactory. But there is another reason why I avoided the question. I do not know, and I have not yet heard, how the *times* of the evolutions of a twin screw ship correspond with her circle. In 1862 some experiments were tried with Ruthven's propeller in a gunboat at Plymouth. That power, when applied in a line with the keel, drove the gunboat five knots and a half, dragging the screw. It was presumed that the power of Ruthven's propeller and the screw—from such experiments as could be made—were equal. When that power was applied at right angles to the ship, it is true she turned round in smaller space, but, instead of taking two minutes and a half to turn, she took three minutes and a quarter. I am not quite sure that in the case of twin screws we should not find something like that to be the result; that the space would be smaller, but that, after all, you would still, by the ordinary use of the rudder, describe a circle in a shorter time, therefore, complete your evolution in a shorter time. I would not for one moment allow it to pass, as Captain Selwyn appears to imagine, that I advocate the idea of using sails in action, or even think of it. My idea of going into action is that I get every single thing down from aloft, and trust entirely to the steam, and if the steam fail, I say that there is an end of it; nothing more is to be done. What I say is this, that the expenditure of coal for drill, is an expense that the country will not bear and cannot be made to bear. Supposing the coals at 15s. per ton, a day's evolutions with twelve ships would cost between five and six hundred pounds. Now, if you have to drill up your ships at that expense, the country cannot stand it. Therefore, my view is that, having your masts and sails,—and you must have them with your screws on account of the expense,—you should make all the use you can out of them, in order to get into the habit of manœuvring your fleet with steam. Whether it be true that we shall never have the fleet formation again, that I cannot say; but I cannot think that any English Admiral will imitate the High Constable of France, and when in the presence of the enemy say, "The Devil take all order, I'll to the throng."

The CHAIRMAN: I am sure you will allow me to thank Captain Colomb for the very useful and well-drawn up paper that he has given us. Whether the future shall be as we anticipate, and we have no more fleet evolutions, it is very important that the subject should be studied, so that, whatever may be the evolutions for the future, the Captains should be prepared for them. With respect to the twin screws, I think it is a mere question of difference of degree. The twin screws, doubtless, have the advantages claimed for them by Captain Selwyn; still I do not think that they nullify the necessity of having steam evolutions. It is a question of degree, of difference of time in which the evolutions may be performed. But evolutions will have to be performed, and if you can effect them in shorter time it will be an advantage. The objection which Captain Selwyn has taken to the difference of speed in ships is a very serious objection. To have a vessel that is equal to fifteen knots tacked on to a vessel of only seven knots would be a defective kind of fleet. It would be better to have all ships of fifteen knots, or all ships of seven knots.

Sir F. NICOLSON: The seven knot vessel is the newest.

The CHAIRMAN: I think it is very objectionable. The study of evolutions would bring out the necessity for having the ships constituting a fleet more equalized in their capabilities. I have much pleasure in returning thanks to Captain Colomb for his clear and instructive lecture.

APPENDIX.

London, 17, King-street, St. James's.
February 25th, 1865.

Sir,—

As Chairman of the Meeting of the Royal United Service Institution on the 20th of February, after Captain Colomb had finished his very remarkable lecture on Modern Naval Tactics, you did me the honour kindly to ask me to make what remarks the lecture might have suggested to me. Your call took me by surprise, since I came only to *listen*, as much as my imperfect organs of hearing and knowledge of English would permit me, and not to *speak*, which is a difficult task for a foreigner. Being, therefore, entirely unprepared, I was constrained to excuse myself for not offering any remarks, and I am afraid I muttered my excuses in a no very intelligible manner. That there might not remain an idea that I had not duly appreciated the kind and gratifying manner in which my work on Tactics and my name as the author of it have been mentioned on that evening, I beg to trouble you with these few lines, in order to say that if I had been at all up to the task of making any remarks on the aforesaid evening I should have answered your summons by expressing my admiration of an Institution so highly useful, and by saying that I would be very sorry if the chance of my presence in it at the time of this lecture should, from motives of delicacy, restrain in the least any one present from making whatever remarks and criticisms he should consider just to make on a subject of such great importance.

As for myself, since Mr. Whitworth, very appropriately, I think, calls a gun a *tool* for accomplishing a certain work, I may call a ship a *tool* in the hands of her Captain, and a Squadron a *tool* in those of the Admiral. The general impression Captain Colomb's lecture produced upon me is, that this new tool, in the present transition times as regards naval matters, requires a new manner of using it.

Since it is impossible to predict what new propellers and modes of propulsion may come in use in the future navies, it appears to me that the present mode of propulsion is the only one requiring for the moment the immediate attention of those concerned. And since the single screw with the single rudder in all movements of ships or congregations of ships produces only circles and tangents to circles (the latter either straight lines or arcs of circles), the circle and tangent seem to me to be the only basis now existing for regularizing those movements and wielding these tools in the most efficient manner.

When driving four-in-hand, what allows the driver to do it effectively? The equal speed, the equal turning powers, and in hand he has his four-horse powers; in fact, he has in them natural uniformity. How much more is not the same required when, instead of four individual forces, you have hundreds and thousands of them to keep *in hand*, whether for simple locomotion or for manœuvring for the best position and the best formation before you come to use your tools? If in the present ships you lack natural uniformity, must not you supply this deficiency by artificially producing uniformity—viz., uniformity of speed and uniformity of circles? If the driver had not bridled and harnessed his four horses to obtain uniformity of speed, they would be only a herd of wild cattle, and the lack of uniformity in turning, would soon remind one of the swan, the pike, and the crab, harnessed to produce the same movement!

If, however, I should allow myself to peep into future possible contingencies; if I were to suppose that instead of using to its full effect the column of water which we now have at our command from the single screw for turning purposes; if, I say, we should use propellers which will allow to turn a ship on her heels, even in that contingency I consider the readiest means of turning and twisting the squadron in any requisite position, to consist in the same laws which the combination of circles and tangents affords us. We shall then only have to turn the ships on their heels to an *angular* amount corresponding to the *arcs of circles* which now forcibly enter into the laws of evolutions.

As regards what we have heard on the 20th of February about the question of

drilling a squadron, I can only say that in sailing times squadrons were well drilled during their cruises, and if we have now more expensive tools, we must have more expensive drills for attaining the requisite efficiency. The difference, in this respect, of present armaments from the former ones mainly consists in this, that while we went to sea in sailing ships perfectly prepared from boyhood to what we had to do in a squadron, we now come to sea without that preliminary schooling. Let it be provided for, and the difficulty will vanish. Let it be provided, if preferred, by cheap training squadrons of gunboats and dispatch boats, which could easily work out and simplify any code of evolutions and signals; but let us not think that any system is bad because we have not studied it, that it is complicated because it looks so at a first glance, and because we do not know that it may be very simple in application when once understood. There is a saying in Russia that pewter pots are not manufactured by gods, although I, for my part, confess I do not know how to produce them.

Believe me,

Your very obedient humble servant,

GREGORY BOUTAKOV,

Rear Admiral, Russian Navy.

Captain Fishbourne, R.N., Member of the Council of the R.U.S.I., and Chairman of the Lecture of 20th February, 1865.

LECTURE.

Friday, January 27th, 1865.

General Sir JOHN F. BURGOYNE, Bart., G.C.B., Director of Works, in the Chair.

PONTOONS.

By Lt.-Col. J. W. Lovell, R.E., C.B., Instructor in Field Fortifications, R.E. Establishment, Chatham.

Among the various obstacles to the free movement of troops engaged in active operations in the field, those due to the presence of water in some one of the forms in which it collects upon the surface of the earth, are of very frequent occurrence, and the advantages to be gained by moving an army over these obstacles have been so plainly manifest in numerous instances, as to have amounted to a necessity for the operation being effected. Hence we find that from the earliest ages up to the present day, many persons have devoted both time and attention to the study of the best means for crossing these obstacles.

In order to form an idea of the importance which should attach to the art of forming military bridges, as they are termed, it is only necessary to picture to the mind the almost infinite variety which is presented, both in the form and feature of the banks and beds of the many rivers in the world, and also in the condition of the water which flows down them, from their rise in the mountains to their junction with the ocean, and then reflect that upon the power of rapidly effecting a passage from one side to the other of a stream or other piece of water under some one of these conditions, may depend not only the safety of a body of troops, but also the success of the operations in which it is engaged, and therewith the safety and honour of the cause for which it is striving.

Without wearying you by attempting any detailed description of all the varying circumstances of bank and other conditions under which it may be necessary that a passage should be made over a piece of water, it will be sufficient to divide them into two classes, those where the depth of water and other circumstances admit of the employment of floating vessels, and those where, in consequence of these vessels being inapplicable, it is necessary to resort to other measures for transferring the troops over the obstacles.

I purpose calling your attention to-day only to the former of these two classes, excluding the latter, not on account of any want of

importance to be attributed to the means and methods required for forming bridges over them, but simply because the special subject of this paper does not bear any part in the operation.

It appears probable that from very early times the practice obtained, of armies conveying with them in the field some description of vessels which could be and were used for crossing rivers, but it is said that it was not until the period of the Thirty Years' War, that armies, gradually increasing in numerical strength, found it necessary to provide themselves with regularly organized bridge trains, which, together with a trained body of men, always accompanied them in the field, and which comprised a certain number of buoyant vessels carried upon waggons, together with other stores and materials required for the formation of a floating bridge, which usually consisted of a roadway of planks laid transversely upon a series of beams, which were supported at their junctions by the floating vessels moored at equal intervals across the stream by means of cables and anchors.

Besides being employed as the supports of these floating bridges, the buoyant vessels of these equipments were made use of either singly for ferrying troops, or connected together into rafts for transporting artillery, cavalry, &c., over rivers, for the passage of which, floating bridges were inapplicable, either on account of the great breadth of the water or other causes.

Bridge trains of a very similar character have been retained by most nations up to the present time, but many changes have been made in the various details of the equipments, more particularly in regard to the buoyant vessels, which are now generally included under the name "pontoons," whatever may be the peculiarities of their form and construction, although specific names are sometimes employed to distinguish different kinds of vessels.

It will be sufficient, then, to define a pontoon, as one of the component items of that part of a portable bridge equipment which is designed for the purpose of enabling a body of troops to cross at will over any piece of water, of which the depth and other circumstances admit of the employment of floating vessels of this class; and in order to form a just opinion of the merits or demerits of any particular description of pontoon, it is necessary to examine, in the first place, whether the equipment of which it forms a basis, is capable of fulfilling the required conditions, and if incapable, then to consider whether the principle of construction of the pontoon admits of application to an equipment, which shall be satisfactory.

It appears, desirable, therefore, to place before us at the outset the conditions required in a bridge equipment, in order that it may be thoroughly efficient.

In all the changes which have been made, either in the floating vessels, or in any other of the component parts of a bridge train, the chief object sought for appears to have been at one time to obtain an increased degree of mobility at the expense of the power of the bridge, and at another to gain additional power at the expense of mobility, according as the mind of the proposer of the change has become biassed by what he may have seen or read of the causes of failure in

the efficiency of bridge trains; and it appears only natural that a pontooneer should feel inclined to sacrifice power for the sake of mobility, after having been subject to the extreme annoyance of feeling that the want of success in a series of skilfully designed operations, was due to the tardiness of the movement of his bridge train, while on the other hand, one who had witnessed the failure of a bridge from want of power, would be equally inclined to insist upon that as the chief feature to be attended to in a bridge equipment.

It is indeed difficult to decide which of these two qualities should rank as of first importance in a bridge train, but as the bridge cannot be constructed unless the material is on the spot, the mobility of the train may be considered as the first point to be attended to, although the power of the bridge at the same time must be equally insisted upon.

The conditions required in a bridge equipment, arranged in the order of their relative importance, may be considered to be as follows:—

1. It should possess sufficient mobility to accompany, or even to advance in front of the troops to which it is attached, so that there may not be any delay in their crossing over the river or stream.
2. That the material should be so constructed and so arranged upon the waggons as to admit of a very rapid construction of a bridge where practicable, or of the pontoons being employed, either singly or in rafts, where that mode of transport becomes necessary.
3. That the bridge, when constructed, should afford a safe passage to an army under the various circumstances of war, over a river or stream, in any condition under which such an operation may be possible.
4. The material should be durable and easy to repair.

The first point is to decide on the degree of mobility which should be given to a bridge train, and it may here be premised, that our present question is entirely as to what is suitable for an army fully organized and equipped for a campaign against a similar force, and not with the special equipments which may be necessary for warfare of a more desultory character.

General Birago, of the Austrian army, has collected together a great number of accounts of operations in which bridge equipments have played a part, and as the result of his study, he insists very strongly, that a bridge train should always be capable of moving at least as rapidly as the troops to which it is attached.

In the middle of the 17th century, the bridge equipments in use by the Duke of Brunswick, Tilly, and other generals, consisted of very large and heavy bateaux, the other parts of the material being of a similar nature; the waggons for the transport weighed when loaded about 60 cwt., and required from 12 to 14 horses for their draught, but as at this time the artillery waggons were equally unwieldy, there was not any great disproportion between the mobility of the bridge train and that of the army generally, of which of course the artillery formed an integral part.

Shortly after this, however, rapidity of movement, both on the march and in manœuvre, was felt to be of great importance in carrying on war successfully, and much attention was devolved, and with effect, to render the artillery more mobile; the bridge trains remained unchanged, and their slowness of movement was a constant source of annoyance to the Commanders of the Armies. On one occasion Prince Eugene, in Italy, after much trouble, had almost effected the junction of his army with that of the Duke of Savoy, but failed in consequence of his bridge train arriving one day too late at the point selected for crossing the river which divided the two armies, and this delay gave time for the enemy to collect such forces to dispute the passage, that the Prince deemed it imprudent to attempt it. The consequence of this was, the necessity for fighting a bloody battle without any good result, while the desired junction of the Austrian and Sardinian armies was not effected until some months afterwards.

During the early wars of the French Revolution, bridge trains were employed, of which the waggons weighed 54 cwt., and were drawn by 10 horses, and notwithstanding that every effort was made to urge forward these trains, even by using fresh horses every day, they never could be advanced beyond the rear guard, so that, if the necessity for crossing a river had arisen unexpectedly, the bridge material would have been of no service, or at least there would have been great delay before the army could have made use of it, while if a sudden retrograde movement had been necessary, the bridge train must have been abandoned.

The despatches of the Duke of Wellington also may be quoted as animadverting in very strong terms on the want of mobility of his pontoon train, more particularly in his advance to the Adour.

The fact that rapidity of movement is one of the chief, if not the chief element of success in war, is becoming daily more and more fully recognized and acted upon, and there cannot be a question, that the mobility of a bridge train should be developed to as high a degree as is compatible with its thorough efficiency in all other respects; we may say, in fact, that it should be capable of accompanying an advanced guard, or even a detached flying column; with which view, the weight of the loaded waggons should not exceed that of field artillery carriages, and the same proportion of horses should be allowed for their draught, that is, one horse to every 800 or 900 lbs.

There is also another consideration which affects the mobility of a bridge train, namely, the capability of the waggons for turning in narrow lanes, or in streets in towns, &c. This depends on the interval between the fore and hind axles, the angle to which the front wheels will lock, and the length of the materials which are placed on the waggon; and is more a question affecting the construction of the waggons than the pontoons, although the dimensions of the latter govern those of the other stores carried on the waggons, and therefore the space in which the waggons may be turned.

In the event of England engaging in a foreign war, her pontoon train necessarily would have to be conveyed across the sea, and the question of stowage on board ship has been regarded as of considerable

importance; but the efficiency of the bridge being the primary object, it would not be judicious that this should be sacrificed for such a question, the difficulties of which would be overcome by hiring a ship specially for the transport of the equipment.

The rapidity with which a bridge may be formed, appears a point worthy of much attention, in considering the pontoons, carriages, and other material of a bridge equipment.

The battle of Fredericksburg gives us a very important example of the value which this quality might have in the course of an action. You may remember that General Burnside, at the head of about 125,000 Federal troops, had for a month been facing General Lee, who, with his army of 85,000 Confederates, was in position on the south bank of the Rappahannock, when his pontoon trains having arrived, the Federal general determined to force the passage of the river, and with that view ordered the formation of five pontoon bridges. The breadth of the river I have not been able to trace, but it appears that, notwithstanding that the construction of the bridge was commenced at early dawn, and that the operations of the pontooneers were uninterrupted in consequence of their being concealed by a heavy fog, the bridges were not completed when the fog cleared away about 9 o'clock in the morning, when of course the pontooneers were discovered, and the fire of a very small party of the enemy's sharpshooters on the south bank stopped their operations, and the bridges were not completed till 5 o'clock the same evening. It appears uncertain whether the length of time required to complete these bridges was due to the nature of the material employed, or to want of skill and practice on the part of the pontooneers.

In the accounts of the battle of Magenta, and of some other actions in the late wars in the north of Italy, we read that part of the troops engaged, advanced over bridges which were constructed during the course of the action; and as the numerical strength of armies becomes greater, and the range of artillery and rifles is increased, the area of battle fields will become more extended, and it is probable that bridges will play a larger part in assisting the movements of troops, and the necessity for their quick formation will become more and more apparent.

In order that there should be as little delay as possible in the formation of a bridge with an equipment, it is evidently desirable as respects the material, that as far as possible, each part should be carried on the waggons in such a condition as to require but little adjustment before being placed in bridges; that the method of laying and securing together the several parts should be simple and easy of manipulation; that all the parts should be so constructed that there may be little risk of their being wrongly placed; and that the loads on the waggons should be so arranged that the several parts may be taken off in the order in which they are required, and that if necessary, any one part may be taken off without disturbing the others.

The question of the rapidity of formation of a bridge is involved in that of the relative merits of equipments formed on the principle of small vessels at short intervals, as compared with those of which the

pontoons are larger, and are placed at correspondingly greater intervals, and it may be perhaps desirable to enter here upon that subject.

The operations which have to be gone through in forming a bridge are—unloading the pontoons and carrying them into the water, casting the anchors, and bringing the pontoons into position; unloading and carrying the baulks to the site for the bridge, adjusting and securing the baulks on the pontoons, booming out the latter to the extent of the bays, and carrying and laying the chesses.

The latter would occupy about the same length of time, whether the pontoons are large or small, but with regard to the baulks, it is the practice when they are short and light, that each should be carried by one man, who must necessarily balance it by the middle, in which position, in consequence of the impetus acquired by the unsupported ends when once they are set in motion, he has not much power to direct the baulk in any required direction, and consequently finds a difficulty and delay in adjusting it on the pontoons, and the same is the case while loading or unloading the waggons.

The details of securing the baulks on the pontoons must be the same, whether the latter are large or small, and the additional length of time required for booming out a pontoon for a few feet more or less, is almost inappreciable. The time required for each of the other operations is about the same, whether the pontoons are large or small, and as, when the latter are made use of, these operations, as well as securing the baulks and booming out the pontoons, must be more frequently repeated than when larger pontoons are employed, it may be expected that a bridge would be formed over a given piece of water in the shorter space of time with large vessels, than with others of smaller dimensions, provided the two equipments were constructed upon the same system, and the bridges had the same power.

Although it has not been possible to try experimentally the soundness of the foregoing reasonings with two similar equipments, yet the practice at Chatham with differently constructed pontoons, has shewn, that the advantage in almost every respect as to rapidity, is with the larger class of vessels.

We may now enter upon the third condition required in a bridge train, viz., that the bridge when constructed should afford a safe passage to an army under the varying circumstances of war, over a river or stream in any condition in which such an operation may be practicable.

We see then that the two varying elements must be analysed, namely, the army and the river, before it is possible to discuss fairly the qualities necessary for the bridge.

As respects the army, the points for examination are the width required for the roadway, and the weight which may be brought upon it. And in deciding upon the former it must be borne in mind that, for the sake of the mobility of the train, it is desirable that the weight and dimensions of the pontoons and other details, should be as small as possible, and as these depend upon the greatest weight which can be brought upon the roadway, and this of course is in proportion to its width, it follows, that this dimension should be reduced to the lowest

limit compatible with giving a sufficient space for all parts of the army to cross over, without breaking their regular formation.

Infantry would probably cross in the formation of fours, in which order they occupy a width of 7 feet 4 inches, and including the supernumerary rank 9 feet 2 inches, and with their commander, 11 feet, but as the latter could march at the head of his men, 9 feet 2 inches would be a sufficient width for infantry.

Cavalry would cross in double files, and would require a width of about 6 feet 6 inches, and artillery and waggons and other wheeled carriages could cross over a roadway of the same width.

Experiments have been made at Chatham to ascertain the width which would be sufficient for artillery, and the opinions both of the Officers who were present and the men who were driving, were in favour of a 9-foot roadway, which gave quite sufficient room even with spirited horses, well fed, and not hardly worked.

In the early bridge equipments, the width of the roadway was sometimes 15 feet 6 inches, and generally from 13 feet 6 inches to 14 feet, but when it was found necessary that the trains should be made capable of moving with greater rapidity, the width of the roadway was reduced to about from 10 to 11 feet, at which it remains at present with most nations. Since the war of 1859, the width of the roadway in the Italian bridges, however, has been reduced by means of the grindage and racking down to 8 feet 6 inches, although the dimensions of the chesses have not been altered.

In examining into the weight which might be brought upon a bridge, we must consider the army under three phases; as moving in its normal order; as accompanied by a siege train; and as retreating in a disorganised state.

1. 100 rank and file in heavy marching order moving at a regular pace in formation of fours, and averaging 200 lbs. per man, including kit, ammunition, and provisions, would occupy 90 lineal feet of the bridge, and would cause a load of 222 lbs. on each lineal foot of the roadway.
2. The same men if checked on the march and crowded together without breaking their formation, could stand on 35 feet 8 inches of the bridge, causing a load of 560 lbs. on each lineal foot of the roadway.
3. If crowded together in a disorganized mass, 42 men, in heavy marching order, can stand on every 100 square feet of the roadway, and cause a load of 84 lbs. on every square foot of the surface, the load per lineal foot of the bridge varying with the width of the roadway.
4. With cavalry marching in double files, each file occupies about 12 feet of bridge, and each man and horse weighs about 1,400 lbs., the load being about 233 lbs. per lineal foot of roadway.
5. When crowded at a check, each file would occupy about 8 feet, and the load would then be increased to 350 lbs. per lineal foot of the roadway.
6. When artillery is crossing a bridge, the weight is not uniformly distributed, the greatest being that over the space occupied

by the gun and limber. A 12-pounder Armstrong gun weighs 35 cwt. 0 qrs. 16 lbs., and the points of support of the wheels are 9 feet apart. The load per lineal foot of this space is 437 lbs. With the 12-pounder Armstrong ammunition waggon, this load would be 462 lbs.

7. A 40-pounder Armstrong gun weighs 79 cwt. 1 qr. 7 lbs., and the distance between the points of support being about 10 feet, the load per lineal foot of this space is 888 lbs.
8. 76 unarmed men, such as camp followers, averaging 145 lbs. per man, can stand on every 100 feet of roadway, causing a load of 110 lbs. on each square foot of the surface, and this is the greatest strain to which it is probable that a military bridge would be subjected.

The foregoing loads may be reduced to two classes—those occurring in the ordinary course of military movements, 1, 2, 4, 5, and 6, of which the greatest is 560 lbs. per lineal foot of bridge, and those of an exceptional character, 3, 7, and 8, the greatest being 110 lbs. on each square foot of the surface of the roadway; and in order that a bridge equipment should be efficient, it appears desirable that the material in its normal state should be capable of being formed into a bridge equal to the support of the former of these two loads, and should admit of being quickly arranged, so as to be equal to the latter.

That these requirements are not excessive, is proved by the fact that the bridge train which was in general use in Europe in 1799, sufficed for the construction of bridges with a power of support equal to 849 lbs. per lineal foot of roadway, and yet these bridges failed three times for want of buoyancy. The Austrian pontoons in use up to 1859, formed bridges of a power of 542 lbs. and 827 lbs. respectively, but these were found inadequate, and the dimensions of the pontoons have been increased until the power of the bridges are now 639 lbs. and 991 lbs., and the Austrian pontooneers are of opinion that even these are barely sufficient.

We have next to take into account the nature of the rivers in which pontoon bridges may be employed, both as respects the condition of the water and that of the banks through which it flows. The conditions of water which are most adverse to a pontoon bridge, and which are most important to notice, are a very rapid current, by which the bridge is liable to be swept away; and large waves, which have a tendency to swamp or submerge the pontoon; the combination of the two is a condition which few bridges would resist. In order, however, to reduce the danger from the first to a minimum, it is desirable that the form given to the surface of the vessels should be such as will oppose but little resistance to the flow of the water, while the liability to be submerged can only be overcome by employing completely closed vessels for the support of the bridge, or devising some plan by which open vessels, may at will, be covered over. In tidal rivers, where the current may flow up and down the river during the time that a pontoon bridge is being constructed and in use, it is necessary that the pontoons should be equally adapted to oppose but little resistance to the current from either direction, and

this is found to be of such importance, that I understand it is now in contemplation among the Belgian pontooneers, who practise bridge making in the tidal waters of the Scheldt, to give the same shape to the bow and stern of their pontoons instead of retaining the square stern, which is in use at present.

The question of the most desirable plan for obtaining the increased buoyancy required for the support of the extraordinary loads, may properly be considered in connection with that of the resistance opposed to the current by the bridge. Two methods have been proposed for effecting this object: in one, the pontoons are retained, unaltered in form, but they are placed at reduced intervals; in the other, the intervals are unaltered, but the buoyancy of the pontoons is increased by adding to their length. By the latter arrangement, the resistance to the current is increased merely by the friction of the water against the additional surface of the sides of the pontoons, while in the former it is increased by the force of impact of the water against so many more opposing bodies, the amount of the difference of the resistance varying with the forms of the bows and sterns of the vessels and the degree of smoothness of their surfaces.

With respect to the banks of rivers, there are several features which bear upon the question of the pontoons. The surface of the bank may be at some considerable height above the main part of the bridge floating on the water, which sometimes may be deep close to the bank, and sometimes shallow and gradually deepening off into the bed of the stream; again the river may be liable to sudden floods, by which the relative levels of the bank and the water are of course altered. In tidal rivers this change of level is continually taking place, while at the same time the banks may present either of the features before-mentioned; again, it may be required that a military bridge should be constructed at a site where the pontoons required to support the roadway at high water, may be aground at low water.

Now it is not only necessary that a military bridge should be available under any one of these varying conditions, but it should be so constructed and arranged as to admit of the roadway being so adapted to the changes of the relative conditions of the bank and water, that the passage of the army may not be retarded during the adjustments required.

By several writers on military bridges great stress is laid on the importance of selecting as sites for bridges such parts only of rivers as offer conditions which are favourable chiefly from a constructional point of view, but there may be, and there will be frequently in future wars, strategical reasons for sites for bridges which will far outweigh all other considerations; and it therefore appears to be imperative that a bridge train should, if possible, be so organized and equipped, that a General may feel sure that his pontooneers will be able to construct a bridge at almost any point where it may be required for the due execution of any of his combinations. It is with this view that it appears desirable to place before you the foregoing conditions of site, which present perhaps the greatest difficulties to the construction of floating military bridges.

An instance of giving to the details of water and bank, an undue preponderance over strategical reasons, in the determination of a site for a bridge, appears to have occurred in 1859, at the battle of Palestro. The Sardinians on the right bank of the river Sesia held the town of Palestro, which was the chief point of attack of an Austrian army of greater numerical strength. The French, who were to support the Sardinians, were on the left bank of the river, and they, on account of their facilities for construction, made their bridge in such a position, that if the Austrians had been successful in their attack upon Palestro, the passage over the bridge would have been impossible, and, as it was, in the course of the action, the Austrians brought some of their artillery to bear upon the bridge; and had it not been that some of the French Zouaves discovered that the river was fordable, and by that means crossed and fell upon the flank of the Austrians, it is probable that further hindrance would have been given to the passage of the French troops.

To return, however, to the subject of the banks of the river. If an army requires to pass from a high bank to a bridge floating on the surface of the water, on a lower level, it is evident that they can only do so by means of a ramp, having such a slope as is easily accessible to cavalry and to wheeled transport; and if the water close to the bank be deep, the supports of this ramp must rest upon the floating vessels or pontoons, which must consequently be of sufficient dimensions and strength to sustain these supports; and as in rivers subject to floods or the influence of tides, the relative levels of bank and water are liable to fluctuations, so the construction of the supports to the ramp must be such as to admit of the inclination of the roadway being readily altered in proportion.

The question of the stability of the roadway of these ramps has a certain influence upon the dimensions which should be given to pontoons, and will be alluded to in a subsequent part of this paper.

In a tidal stream, with a shelving bank, or where the receding water leaves the bed of the river dry or nearly so, it is evident that the same pontoons which at high water supported the roadway by their buoyancy would be obliged to do the same by the innate strength of their frame when resting upon the bottom at low water, unless some special contrivance is provided for relieving them of this strain.

Besides the foregoing, there is a special quality required in a bridge which is influenced by, and has also an influence upon, the form and dimensions of the pontoons or floating supports of the bridge—I allude to the stability of the roadway.

The surface of the roadway of a floating bridge is subject to two movements, and to combinations of these movements; but it will be sufficient for us to consider only the movements *per se*.

1. An undulating movement in the direction of the length of the bridge which is due sometimes to the waves on the surface of the water, and sometimes to alternate rising and falling of the pontoons when influenced in succession by a load which is unequally distributed over the surface of the roadway, such as occurs during the passage of a gun carriage over the bridge.

2. Transverse or lateral oscillations of the roadway, which are caused at one time by the undulations of the surface of the water, and at another by the passing loads not acting directly over the centre of floatation of the pontoons.

When the first of these is excessive, horses, in passing over the bridge are at one moment ascending and at the next descending an inclined plane, and during the passage of artillery, this alternate pressure upon the breeching and drag upon the collar, makes the horses unsteady, and this unsteadiness is, of course, increased if at the same time the horses feel the roadway sinking with them first on one side and then on the other. A similar result is observable during the passage of cavalry, and the movements of the horses of the latter being less confined than those of the artillery horses, their feet are more likely to get over the side of the roadway.

In order to lessen the risk of this accident occurring on an unstable bridge, it would be necessary to increase the width of the roadway, and this would entail a greater amount of buoyancy in the pontoons in order that they might be able to support the increased load which might be brought upon the bridge. The opposite course of reasoning would show that the more stable and firm the roadway, the narrower it might be made, and the less buoyancy would be required in the pontoons.

The relative stability of the roadway of floating bridges may be considered as follows, leaving out of account the motion due to the waves:

First, the degree of inclination of the undulations in the direction of the roadway, varies with the depth of the immersion of the pontoon supporting the load, and the distance from it to the next pontoon being greater when the immersion is more and the distance less, these features are co-existent with small pontoons, and it follows that, in order to diminish undulation, it is necessary to employ large pontoons at long intervals: that is under the supposition that we are now speaking of vessels of similar form; but when we examine into the influence which the form of the pontoon has on the undulation of the roadway, it will be evident that the longer and broader the vessels, the less will be their depression under a given load, and consequently the less the inclination of the undulations.

With respect to the transverse oscillations of the bridge, if we suppose the width of the roadway to be the same in bridges supported upon pontoons of different forms, the force which causes the oscillations will be the same whatever be the form and dimensions of the vessels, but the counteracting forces are, on the one side of the roadway, the displacement of the additional portion of the pontoon submerged, and on the other, the weight of the disturbed pontoons, each acting at their centres of gravity, the centre of motion being assumed to be midway between the two. Now the power of these forces being a junction of the length, width, and depth or depression of the disturbed portions of the pontoon, and the distance of their centres of gravity from the centre of motion, it follows that in order that the depression of the pontoon or the oscillation of the roadway should be small in

degree, it is necessary that the pontoons should be long and broad. In fact, the degree of oscillation will be inversely in proportion to the breadth of the pontoons multiplied by the square of their length.

Another point is involved in the determination of the size of the pontoons, which is, that the weight of the various details of the equipment should not exceed that which may be handled with facility by the number of men which can be allotted to carry them.

This refers more particularly to the baulks, of which the number to support each bay of the bridge depends upon the number of men which can work at the head of the bridge, where the adjustments of all the baulks must be carried on simultaneously, and this could not be effected with rapidity if the men were too much crowded. The same consideration governs the number of men which it is advisable to allot to carry each baulk, and which should not exceed two.

We see then that the intervals between the pontoons should not be so great, that baulks capable of carrying the load which could be brought upon the bay would be of greater weight than could be handled easily by two men, which is found by experience to be about 120 lbs.

Another application of pontoons besides that of bridge making should also be kept in view, namely the ferrying of troops and artillery over rivers, which they should be able to do, either when used singly or else when formed into rafts. This quality of pontoons is very much insisted upon by foreign pontooneers, and its value was shown in a most remarkable manner at the passage of the Alsen Sound by the Prussians, in the late war with Denmark.

The Sound is said to be 1,000 yards across and of considerable depth, and the water flows through it with a very rapid current. At the time of the passage, the shore opposite to the Prussians was lined with numerous well-armed batteries and entrenchments. Under these circumstances, even if the condition of the waters had been such as would have admitted of the construction of a bridge, yet in consequence of the time required for its construction, which at 6 feet per minute would have been 8½ hours, the operation would most certainly have been discovered, and the concentrated fire of the batteries would have prevented the completion of the bridge. Under these circumstances it was decided to ferry the troops over in open boats, and this was effected by means of 160 boats and 32 pontoons, which at each trip conveyed across the sound about 3,000 men. From the account of this operation, which has been published, and which is very bare of detail, it appears that two divisions of the army, with two field batteries and a regiment of cavalry, were conveyed across in about 5 or 6 hours, and with very little loss. It is to be hoped that a correct and detailed account of this very remarkable operation will be published, as it would afford very valuable hints to the pontooneer.

Another instance occurred at the battle of Fredericksburg, where, as before mentioned, the formation of the Federal pontoon bridges was completely stopped by the fire of a few Confederate sharpshooters upon the opposite side of the river; and their completion would have been almost an impossibility, if a Colonel in the Federal army had not

crossed the river with 400 men in ten boats, in face of the fire of the sharpshooters, whom he quickly dispersed, and thus enabled the pontooneers to complete the bridges without interruption.

As in most of the countries of the Continent, rivers are met with of such a breadth as to prevent their being crossed by bridges, the necessity for the bridge equipments being so arranged as to admit of the construction of large rafts, capable of supporting artillery, becomes more apparent than seems to have been the case in this country. The floor of the largest raft contemplated in any of the British equipments is about 11 feet by 12 feet 6 inches, whereas some of the foreign bridge trains admit of the construction of rafts of which the floor is 30 feet by 20 feet, and in some cases even larger: the power of the rafts presents even greater dissimilarity, that of the English equipment being about 12,500 lbs., and that of the foreign rafts 68,000 lbs. The instances in which it has been necessary to resort to this means of transport are numerous, but the details of the sizes of the rafts are not particularised.

I have purposely dwelt at some length upon these qualities, all of which, it will be generally admitted, are of considerable importance in a bridge equipment, and should not be overlooked; and I have done so because, from the study of the various systems of pontoons which from time to time have been brought forward, it appears to be evident that in many cases the proposers have merely endeavoured to produce equipments which shall be superior to others having acknowledged defects, and have not duly considered whether those which they themselves have proposed would fulfil the conditions required by an army.

Having now a general idea of what is required in a pontoon train, of which, as before stated, the pontoon is merely an item, we may enter into the examination of the different kinds of pontoons which have been brought forward by different inventors; and for the purpose of assisting in this analysis, I have here arranged in a tabular form (*see* Appendix) the chief details which bear upon the question, of the power of the bridges which may be constructed with the material of various equipments, of which correct descriptions have been available. I have here brought the question of the power of the bridges the more prominently forward, because although, when we consider the whole equipment, its mobility is perhaps the more important quality, yet, in the description of the pontoons alone, the buoyancy appears to be the chief point.

It is not easy to make a correct comparison of the power of the several bridges, but I have endeavoured to do so approximately, as follows:—From the total displacement of each of the pontoons, has been deducted its own weight, with that of its fitments, and that of one bay of the superstructure peculiar to the equipment to which the pontoon belongs, and the remainder is the total available buoyancy or power of the pontoon. In the case of open vessels, this buoyancy has been reduced by one-fourth, to allow for the risk of submersion by the wash of the waves, the oscillation of the bridge, and in closed vessels, a deduction of one-tenth has been made, to give a small

margin to allow for leakages, and this second remainder has been considered to be the power of support of one bay of the bridge; this divided by the distance from centre to centre of the pontoons gives the power per lineal foot of roadway.

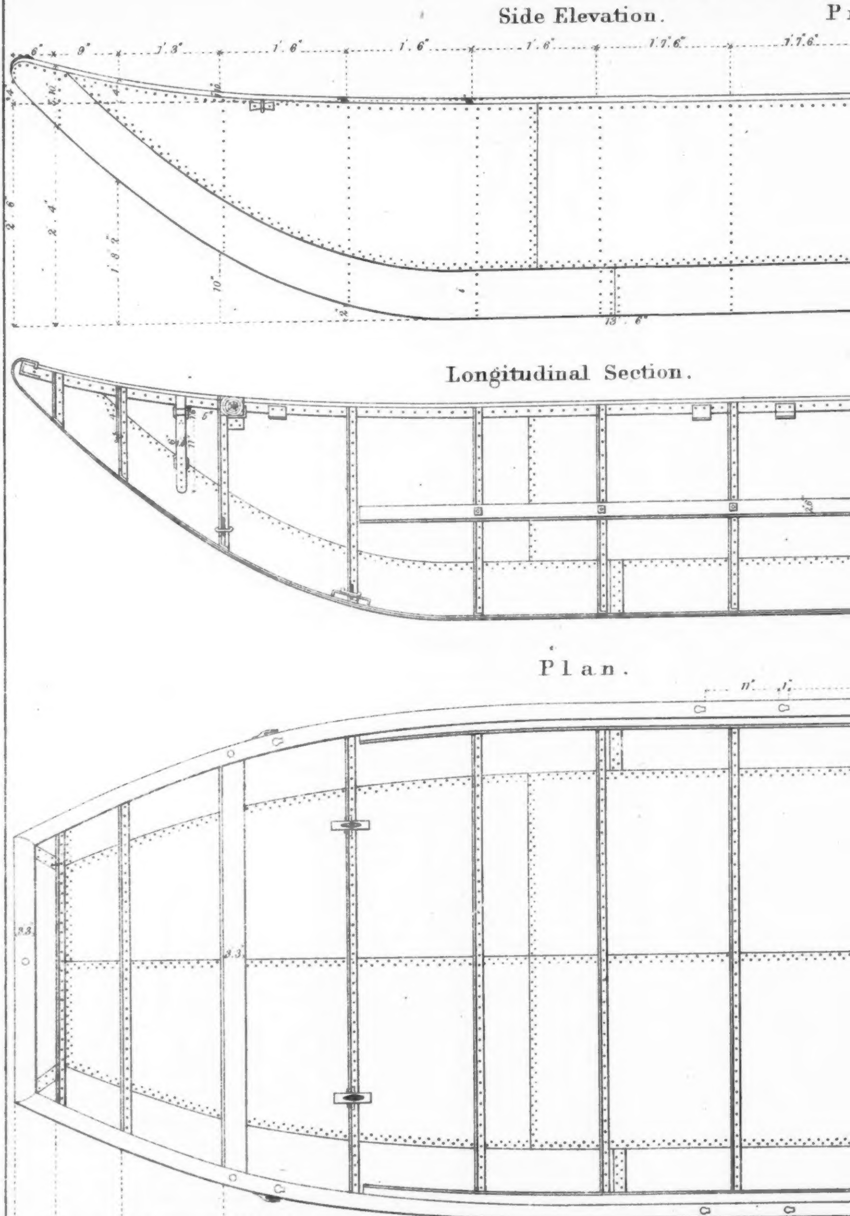
Without going very far back into the history of bridges, it may be well, just to review what has been done by some of the principal nations with respect to their bridge trains.

About the beginning of the present century, the Austrians, who appear always to have paid considerable attention to the subject of crossing rivers, made use of open wooden bateaux, of a pattern which was very generally imitated by other continental nations, and which was introduced instead of the very heavy and unwieldy bateaux, which had been in use up to that period. The bateaux were 27 feet long, 6 feet 1½ inches wide, and 2 feet 8 inches deep, and weighed 1,540 lbs., and each, with its bay of superstructure, was carried on one waggon, weighing when loaded 5,790 lbs. (52 cwt.) The bridge formed with this equipment had a power of 849 lbs., which was found inadequate, having failed upon three occasions. The excessive weight of the waggons also was found a grave inconvenience, and the Austrians gave it up in favour of an equipment of which the pontoons consisted of demi-bateaux of wood, 16 feet long, 6 feet 10 inches wide, and 2 feet 10 inches deep, weighing 864 lbs., and having a buoyancy of 15,064 lbs.; two of these demi-bateaux, coupled together by the sterns, formed one of the supports of the bridge, which were placed at intervals of 18 feet 4 inches. This arrangement was found not to be satisfactory, because the vessels formed with them were not suited to support the trestles which it was proposed to place on them under certain circumstances, and after several unsuccessful modifications was abandoned, and was superseded by another, of which each of the two floating supports of the roadway was formed of two bateaux of wood, each 23 feet 3 inches long, 5 feet wide, and 2 feet 6 inches deep, weighing 617 lbs., and having a buoyancy of 12,101 lbs. When in bridge these two bateaux were placed parallel to each other with an interval of 12 inches between them, and with the bow of one projecting 5 feet 9 inches beyond that of the other, so that the entire length was about 28 feet. The interval in bridge was about 22·10, and the baulks were placed end to end, and rested on a plank between the two bateaux, where they were secured by a hole in each baulk, being placed over pins in the plank.

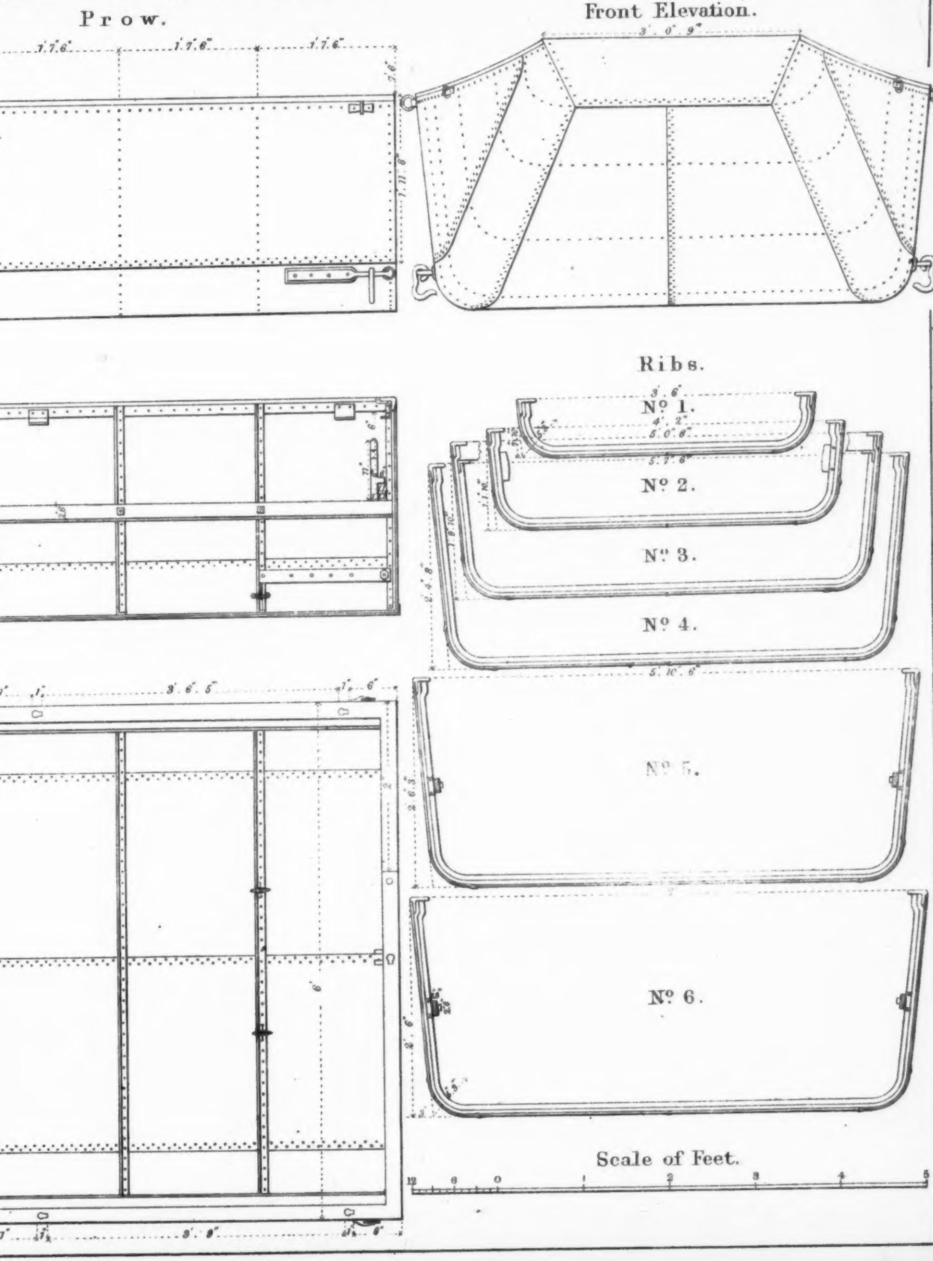
This equipment was found not to be satisfactory, and was replaced by that submitted by Colonel Birago, which, with some modifications, is now entirely employed in Austria, and forms part of the pontoon equipment of most continental armies.

The leading feature of the pontoons of this system is the same as that proposed by Colonel Pompei Floriani about the early part of the 17th century, which consisted in dividing transversely into three parts, a long flat-bottomed bateau, of which the bow and stern were of the same shape. Each of these parts has about the same amount of buoyancy, and they are so constructed that all the parts are interchangeable.

AUSTRIAN



IAN IRON PONTOON.

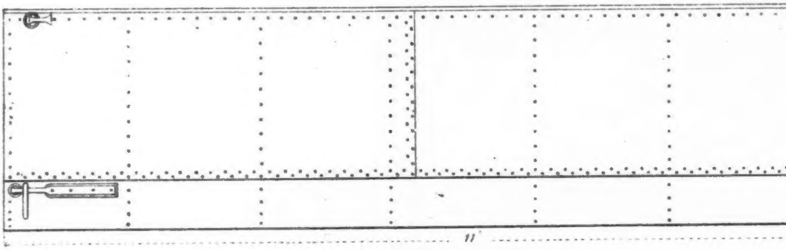


VOL. 9.

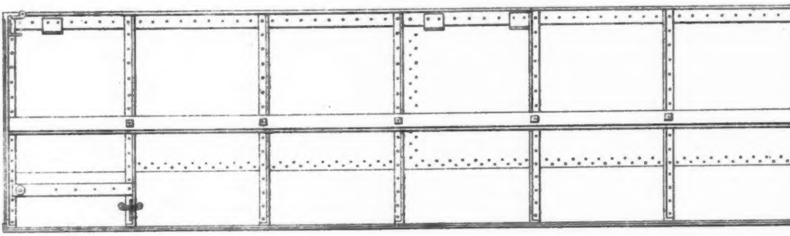
AUSTRIAN IRO

Side Elevation.

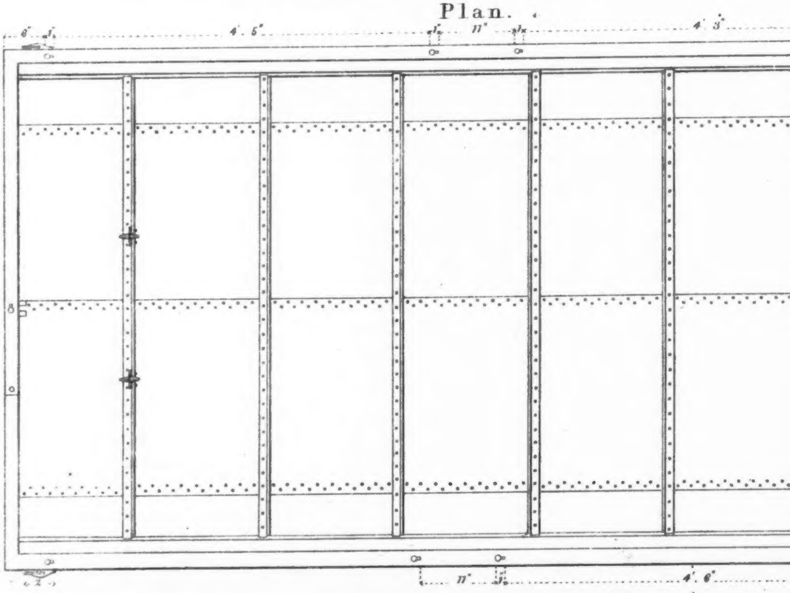
Midd



Longitudinal Section.

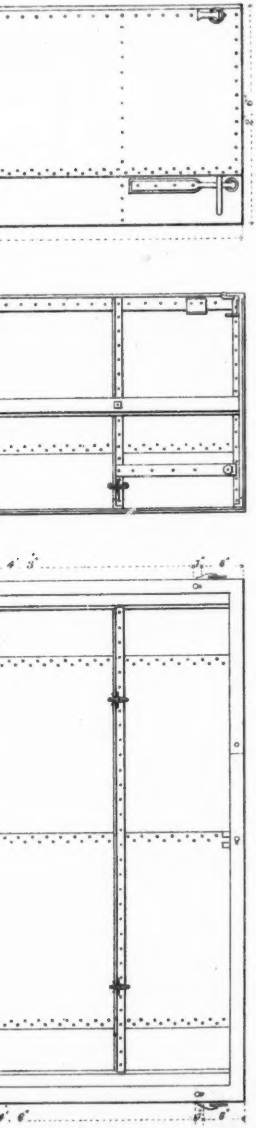


Plan.

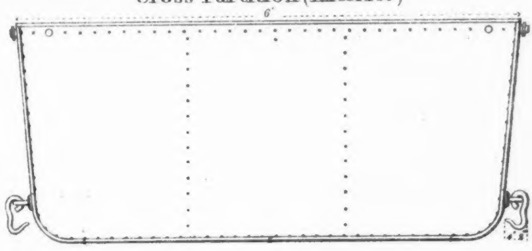


IRON PONTOON.

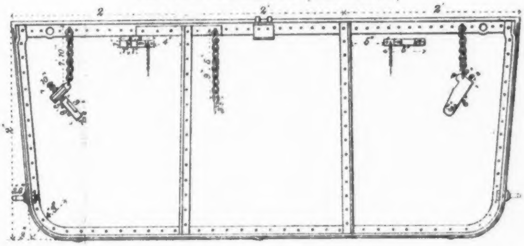
Middle Piece.



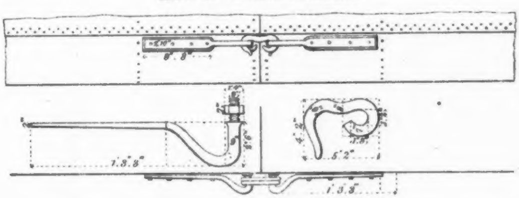
Cross Partition (Exterior)



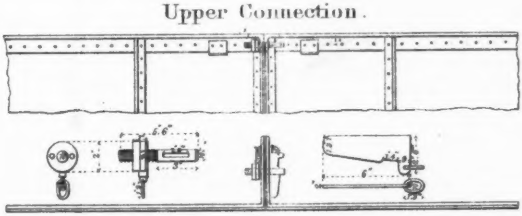
Cross Partition (Interior)



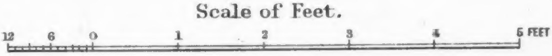
Lower Connection.



Upper Connection.



Scale of Feet.



J.R.Jobbins.

When the bridge is prepared for ordinary loads, each of the floating supports of the roadway is formed either of two end pieces, or of one end and one middle piece, connected together so as to form one bateau; in the former case having the bow and stern similar, and in the latter having a square stern. In rapid and broad rivers, where more power and stability are required, the pontoons consist of two and three pieces alternately, and when very heavy loads are expected, every pontoon is formed of three pieces, the additional buoyancy being thus gained without much increase to the obstruction opposed to the current by the bridge.

When required for rafts or flying bridges, the supports are often made by connecting together four or even five parts of the vessels, by which means very great power of floatation is obtained.

As originally proposed by Colonel Birago, the bateaux were of wood, and the dimensions of the parts were as follows (see Plates VII and VIII):—

The transverse section of each portion of the pontoon was the same, the width at the top being 6 feet 4½ inches, and at the bottom 4 feet 6 inches, the depth being 2 feet 5 inches. The length of the bow portion was 14 feet, the weight 642 lbs., and the buoyancy 9,454 lbs.; the middle pieces were 11 feet 4 inches long, weighed 637 lbs., and had a buoyancy of 8,884 lbs. The length of the three-part pontoon was 39 feet 4 inches, and its buoyancy 27,792 lbs. The length of the two-part pontoon was 28 feet or 25 feet 4 inches, and its buoyancy 18,900 or 18,300, according as it was formed of two bow pieces, or a bow and a middle piece. The powers of the bridges were 849 and 530 lbs. respectively.

About the time of the Italian war in 1859, it was found that these pontoons had not sufficient power, and others were introduced having the same length as the original pattern, but of a larger transverse section, the width being 6 feet 2½ inches at the top, 5 feet 8½ inches at the bottom, and the depth 3 feet 7 inches, the additional height or depth being given with a view to obviate the necessity for making use of a canvas wash strick about 9 inches high, which was placed along the gunwales of the original pontoons to prevent the waves from washing into them in windy weather. The pontoons of the new pattern consist of a frame-work of angle or ∠ iron, on the exterior of which are rivetted flat sheets of iron, of which the portions at the bow and the junction of the bottom and sides are stouter than those which form the bolts; and these again are thicker than the sides, which it is found are least subject to blows or other causes of injury. By the new construction, the buoyancy of the parts have been augmented from 9,454 and 8,884 lbs. to 11,045 lbs., but at the same time their weights have been increased from 642 and 637 lbs. to 863 and 806 lbs., the buoyancy of the two descriptions of pontoons being increased from 27,791 to 33,000 lbs., and from 18,300 to 22,000 lbs.; and the powers of the bridges from 849 to 991 lbs., and from 542 to 639 lbs.

Some of the authorities in Austria are of opinion that even these large bateaux have not sufficient power, and they are quite open to the conviction that their equipment is not yet so perfect as it should be.

It will be noticed, on referring to the comparative table of buoyancies, that the power of the bridge prepared for extraordinary loads with these pontoons is almost precisely what is theoretically required, while that for the ordinary loads is considerably above the theoretical standard.

Pontoons of the above-mentioned form and dimensions have been made in Austria with sheet iron, corrugated after the pattern proposed by Mr. Francis, an American, the corrugations in the bottom plates being placed longitudinally, and those in the sides and ends being vertical. The vessels so constructed are lighter than those of the adopted pattern, but the projections of the corrugations are found to be liable to injury; and in rapid currents, the action of the filaments of water in the longitudinal corrugations renders it difficult to conduct the pontoons in any required direction.

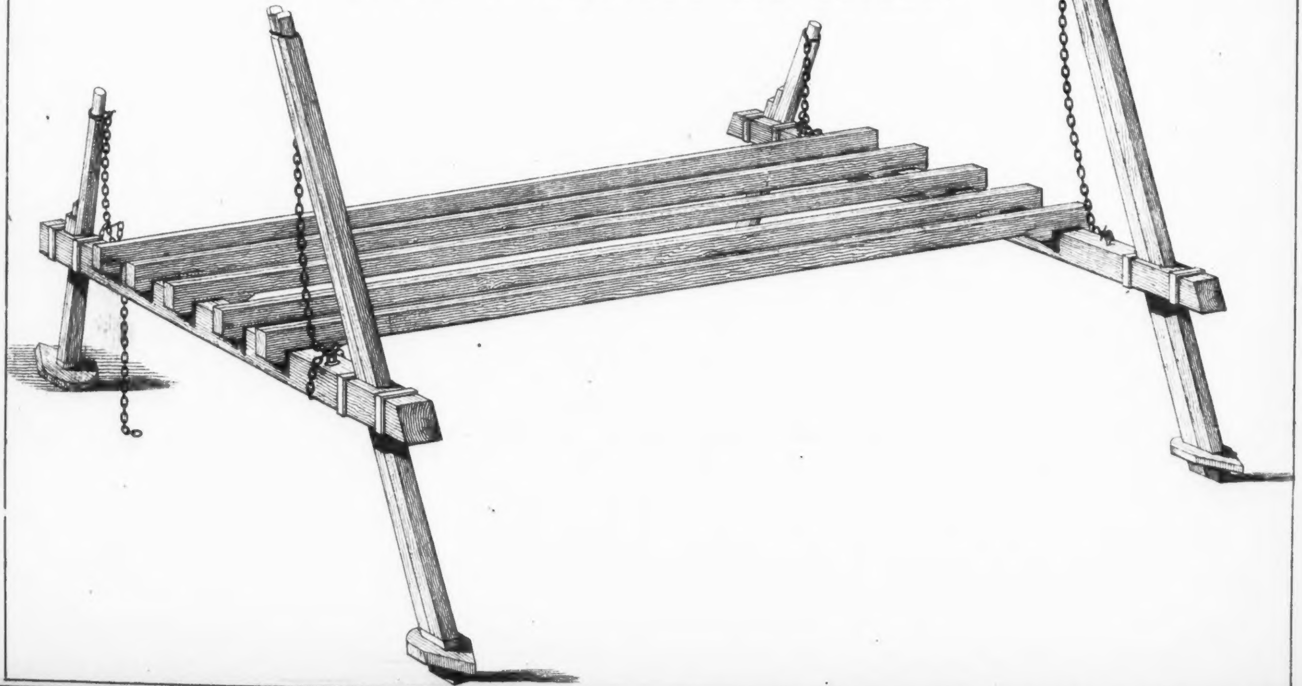
In order that the baulks might be as short as possible, Birago made them to rest on a strong beam supported over the axis of the pontoon on traverses laid across the pontoons from gunwale to gunwale. In the two-part pontoons, the centre of this transom rests on a block of fir standing on the junction of the parts of the pontoon, and having in it a clip of iron turning on a pivot. The baulks, of which there are five to each bay, are furnished at each end with a bracket, in which is cut a notch of the same width as the transom; and these notches being fitted on to the transoms of the adjacent pontoons, keep them at the proper intervals in bridge. In consequence of the ends of the transoms merely lying upon the traverses, while their centres are securely held by the clips, the pontoons are free to move under the baulks; and should the bridge be formed in a part of a river where the current is not perpendicular to the direction of the bridge, the pontoons may be so moored as to swing in the direction of the current without disturbing the alignment of the roadway. This is considered to be a very important advantage, as the obstruction to the current, and therefore the strain upon the anchors, is much less than when the pontoons are rigidly fixed obliquely to the current.

Besides the pontoon, Colonel Birago invented a trestle to be employed instead of the pontoons in shallow water, and to be placed upon the pontoons when it was required to make a descending ramp from a high bank to a floating bridge at a lower level. (See Plate IX.)

The Birago trestle consists of a strong ridge beam or transom suspended by strong chains from the tops of the legs, which, passing through mortises in the ends of the transoms at an angle of about 22°, project above it, and extend slightly over the roadway. The head of each leg is made circular to receive the rings of the suspension chains, and, about 12 inches at the foot, is reduced to form a shoulder which rests on a shoe, employed when the bottom of the river is very soft. The toe of each leg is shod with iron.

Two legs together are generally employed at each end of the ridge-beam, but when one only is used, a false leg is required to fill up the vacant space in the mortise of the transom. The shoes, which are somewhat pear-shaped in section, are made of two thicknesses of oak plank laid with the grain crossing.

AUSTRIAN TRESTLES AND BAULKS.



The same baulks are employed with the trestles as with the pontoons, the width of the transoms of the trestles being the same as that of the transoms of the bateaux.

When the trestles are employed alone for the support of the bridge, it is evident, as they have no lateral stability in themselves, that the whole security of the bridge must depend upon the strength and continuity of the connexion maintained by means of the baulks between the ridge beams of the trestles and the banks of the river; and the same is the case where the trestles are made use of, either resting upon the bottom or on the gunwales of the pontoons.

The operation of raising or lowering the transom of the trestle to suit a varying level in the water, although practicable, is very tedious, and requires so much labour, that it would be almost impossible to make use of them in tidal streams.

The foregoing appear to be the chief defects of these trestles, which, on the other hand, possess the great advantages of being easily placed in the water, and of offering but small resistance to the current.

Besides the bridges formed of three-part pontoons for heavy loads, and those of two-part pontoons for the ordinary requirements of an army, the Birago system admits of the construction of bridges for infantry, supported on single pieces of the bateaux; and the large three-part pontoons allow of the formation of bridges with double roadways, which offer great facilities for the rapid passage of a river, and do not oppose much more resistance to the current than a single bridge.

The Birago pontoons form admirable boats for the transport of troops, one three-part vessel being capable of carrying 60 men without much crowding. The stability of the roadway of the bridges formed with the Birago pontoons is very satisfactory, owing to the great breadth and the length of the floating bodies.

While Birago was thus successful in adopting his pontoons for the formation of bridges of almost any kind which could be required, he did not neglect the essential quality of mobility in the waggons, which, when loaded, weighed about 4,000 lbs., and were drawn by 4 horses. In order however to obtain this mobility, he sacrificed the unity of the load of the waggons by subdividing among several waggons the stores which are absolutely necessary for the construction of one bay of the bridge; the packing of the waggons is also rather complicated; and previous to the construction of a bridge, it is recommended that the whole of the stores of the train should be unloaded and arranged in order upon the bank of the stream, and this is always done by the pontooneers in their practice.

With regard to turning in narrow lanes, &c., the waggons, of which there are four different kinds in the pontoon train, are all so constructed that the front wheels can pass completely under the carriage, so that, with the wheel horses alone in draught, all the waggons might be turned round in a street 23 feet wide between the houses.

Owing to the great size and power of the Austrian pontoons, they admit of being placed at intervals so great, that the baulks, which are far too weak to support the load which might be brought upon them,

weigh 148 lbs., which is more than can be handled with facility by two men, and they would be quite unwieldy if made of dimensions adequate to the load.

As regards the loading and unloading the waggons, the length of the middle piece of the pontoon is 11 feet 4 inches, which is not more than sufficient to allow 4 men to arrange themselves conveniently at each side for the purpose of lifting and carrying it, and this gives a load of 101 lbs. to each man, and in the prows 108 lbs., both of which are more than the generality of men can lift and move with readiness. It is proposed by the Austrians to employ 5 men on each side, but this number would be too crowded to use their strength to the greatest advantage.

The chief defects of the Birago system of pontoons appear to be weakness at the junction of the parts; their excessive weight, which has induced a sacrifice of unity of load in order to obtain mobility; their great size, which has led to the adoption of intervals in bridges, for which baulks of adequate strength would be of unwieldy weight; the weight of the several parts of the pontoons, which, coupled with their shortness, causes them to be unhandy for moving on and off the waggons.

These bateaux, however, form bridges theoretically equal to any load that may be expected, and their length and breadth are sufficient to allow of the employment of trestles either in or upon them. Each cube foot of buoyancy of these pontoons is obtained at the cost of 5·5 lbs. of material in the pontoon and the fitments necessary before it can be placed in the bridge, or 8·8 per cent. of the displacement is expended in the support of the pontoon.

As in all subjects connected with military equipments, the French have taken great interest in pontoons, and have tried many experiments with a view of ascertaining the best description of pontoon, and the most advantageous system of equipment. In their early trains the pontoons were large wooden bateaux, which weighed from 4,500 to 5,000 lbs., had a buoyancy of 45,000 lbs., and were placed in bridges at intervals of from 20 to 25 feet, the power of the bridge being usually 1,250 lbs. per lineal foot of roadway, which was about 15 feet 6 inches wide. The pontoons of this equipment were carried on one waggon, and the superstructure of the bay on another; but even then, the waggons were so heavy and unwieldy that it was found impossible for them to accompany the army in any rapid movements, and these pontoons were superseded by others formed of copper, weighing only 740 lbs., and having a buoyancy of 8,500 lbs., which, in order to obtain the necessary power of bridge, were placed at intervals of 9 feet, when it was found that the strain caused by the current was so great as to endanger the bridge. The same form of pontoon was retained, but the dimensions were increased until the buoyancy amounted to 12,000 lbs., but these copper pontoons were still found to be inefficient, and they were replaced by wooden bateaux of the Gribeauval pattern, so named after the inventor, which were almost a copy of those in use previous to the introduction of the copper pontoons, and were found to have the same defects, and a lighter wooden bateau was introduced,

constructed upon the model of that in use by the Austrians at the commencement of the 19th century. The pontoon and superstructure, &c., required for one bay of the bridge was carried upon one waggon, which, when loaded, weighed 5,800 lbs.; and in the retreat from Russia in 1812 these waggons were found to be so unwieldy that in order to prevent them from falling into the hands of the enemy, they were burnt, although at the time the French pontooneers well knew that in a few days they would be called upon to form bridges for the passage of the French army over the Beresina. Having decided upon discarding these vessels, the French pontooneers, after several changes of unimportant character, introduced, about the year 1829, the arrangement of having two equipments, one for the general purposes of the army, and the other to accompany the advanced guard. The bateaux of both were of wood, and were of similar form to those discarded, but were made considerably lighter; the length of the larger bateaux was 31 feet, their weight, 1,654 lbs., their buoyancy, 20,286 lbs., and they were placed in bridge at intervals of 19 feet 8 inches, the power of the bridge being 635 lbs. per lineal foot of roadway. In order to obtain greater power, the French reduced the intervals between the pontoons according to the load that was expected, The bateaux of the equipment for the advanced guard were much smaller and lighter, their length being 19 feet 8 inches, their weight, 650 lbs., their buoyancy, 9,734 lbs., and the power of the bridge 376 lbs., when the bateaux were placed at intervals of 16 feet 3 inches.

About the year 1853, in consequence of the inconvenience of keeping up these two equipments, they were suppressed, and another was organized, which it was intended should be able to serve for the general purposes of the army, at the same time that it was sufficiently light to accompany the advanced guard. These pontoons had the same dimensions as those of the larger of the two foregoing equipments, but were made of much lighter material, the weight of the pontoon being reduced to 1,323 lbs, and the power of the bridge being augmented to 644 lbs. The pontoons and the superstructure for two bays of the bridge are subdivided between three waggons, each of which weighs 4,400 lbs., and is drawn by six horses, the weight per horse being about 750 lbs. The waggons are so constructed that the front wheels can pass under the truck, so that the carriages alone can turn in a very small space, but as the bateaux and baulks are of great length, the waggons which carry that part of the equipment require a considerable space for reversing.

The disadvantage of this great length of the baulks and bateaux has long been acknowledged by the French pontooneers, who now find that their bridge equipment is so far behind the rest of the army trains in efficiency, that they are now engaged in endeavouring to make some improvement.

The latest change has been the construction of demi-bateaux of wood, precisely similar to half of one of those of the pattern of 1853, and it is proposed that two of these coupled together by the sterns should be used as the supports of the bridge.

The baulks of the present French equipment are laid with double bearings, that is, resting on both gunwales of the pontoons which they

connect, and their length is consequently very considerable, being 26 feet 3 inches. With the view of assimilating the length of the baulks for transport with that of the demi-bateaux, the French now propose to make them in three pieces, namely, a centre portion of length sufficient to span the intervals between the pontoons, and having attached to it at each end, by an iron hinge, a short piece to lie across the pontoons.

We thus see that the French are now starting upon an idea which has been tried and condemned by the Austrians, insomuch that they have found it necessary to adopt a prism or middle piece, in order to add to the powers of the pontoons formed by coupling together the demi-bateaux. As will be seen in the course of this paper, the same idea has been tried in Belgium and Sardinia, and in those countries the inefficiency of the demi-bateaux has led to a gradually progressive increase to their length, until it is now nearly equal to that of the original bateau, and in the Belgian army there appears to be a tendency to a return to the old bateau form, with a bow and stern of a similar construction. It will be interesting to watch the result of this experiment of the French.

Some years ago experiments were made in France with an equipment of the Birago pattern, which are somewhat of the same principle as those upon which they are now experimenting, but so many objections were found at the commencement of the experiments that the series was not carried through, and the pontoons were rejected; a very favourable report, however, was made upon the trestles, and a modification of them was introduced into the service, and now forms a part of the French equipment.

Pontoons covered with copper, tin, steel, and iron, both flat and corrugated, have been tried in France, and all those materials have been condemned for the following reasons:—copper because it is very expensive and is too soft and yielding to stand the wear and tear of service; tin they reject on account of its weakness and liability to rust; and steel and iron are not approved because they are difficult to repair when injured, and because, as they say is found by experiment, the injuries caused by the blow of a musket or cannon shot are much greater than to wood of similar strength. Canvas also has been employed, but without inducing the pontooneers to recommend its adoption. The chief defects of the French bateaux seem to be their great length and weight, which both militate against the mobility of the tram; being constructed of wood, they are very liable to leak after being out of the water for any length of time. They have the advantages of being cheap and of easy construction and repair in any country in which wood may be obtained; their length and breadth is sufficient to admit of the employment of trestles upon them, but their buoyancy is not equal to support great loads without bringing the vessels closer together than is advisable in rapid streams. In this description of bateau 6·6 per cent. of the displacement is expended on the support of the pontoon.

The next equipment to which I have to call your attention is that of the Belgian army, which is very complete in its details and arrangements.

ng
lks
ose
gth
ng
oss

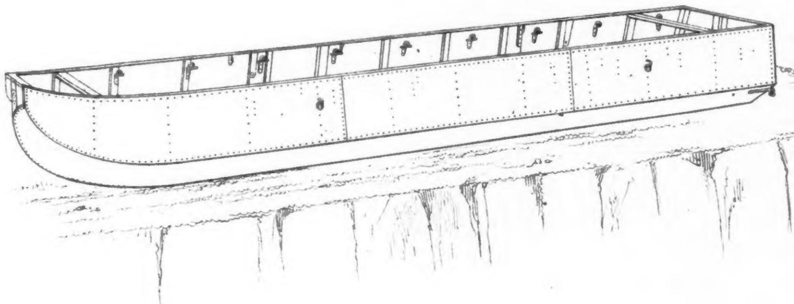
ich
ey
to
he
me
he
ve
he
cy
lar
eri-

ent
as
ons
ies
ery
ifi-
art

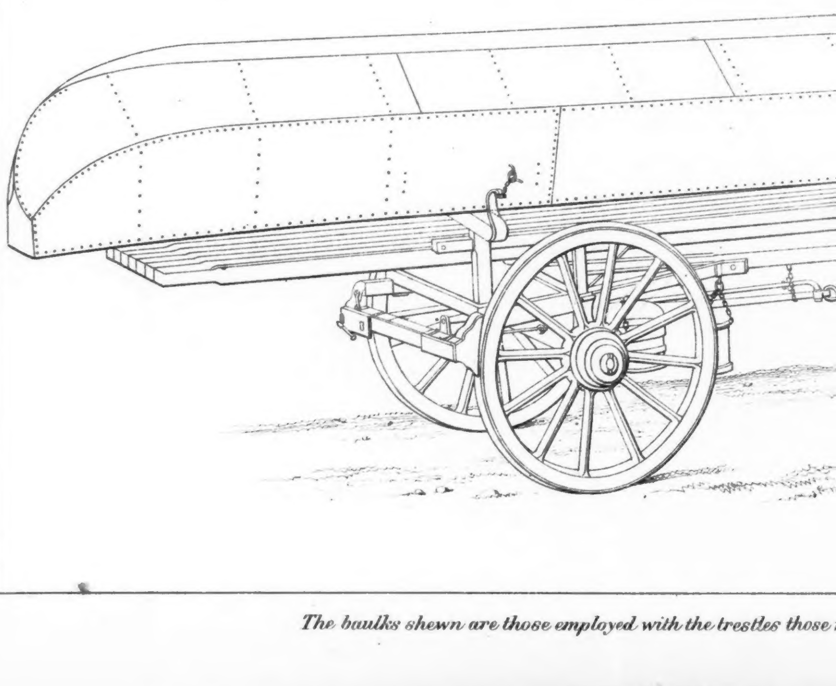
nd
ve
ery
of
to
to
nt,
ch
en
its
eir
of
er
n-
ny
is
eir
he
his
ed

of
e-

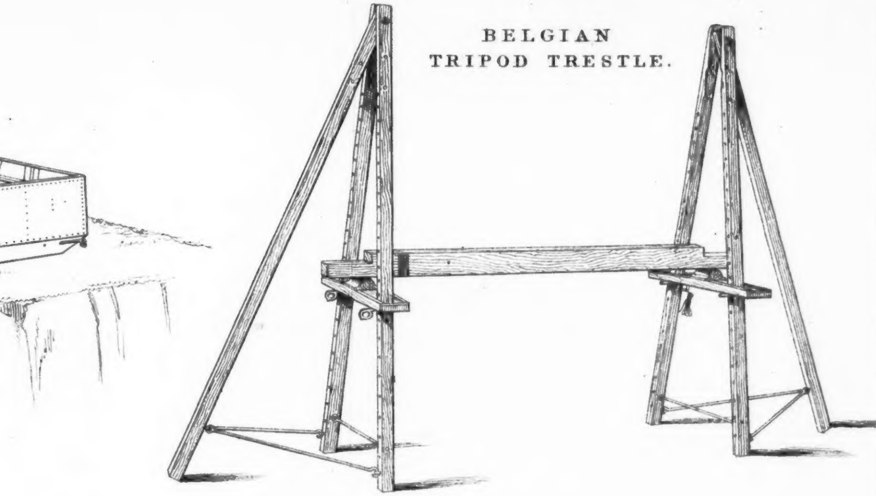
BELGIAN BATEAU.



BELGIAN BATEAU ON ITS W

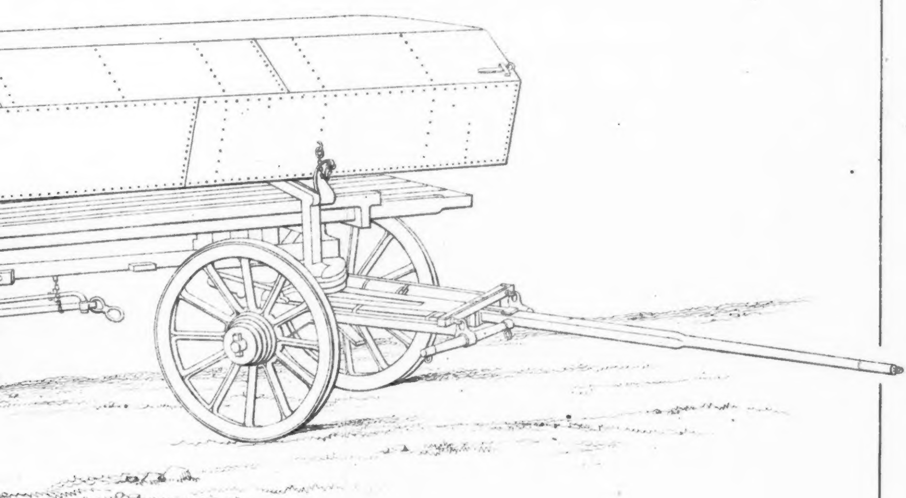


The baulks shewn are those employed with the trestles those



BELGIAN TRIPOD TRESTLE.

N ITS WAGGON.



J.R.Jobbins

estles those for the bateau are $\frac{1}{6}$th longer and project more to the rear.

In this equipment, as in that of the Austrian army, the supports of the bridge are of two kinds, floating and standard, which may be used either separately or combined, and as the Belgian pontooneers practice chiefly in tidal rivers, their equipment is, perhaps, more suitable in some respects to rivers of that class than is that of the Austrian pontooneers, who practice bridge making chiefly in non-tidal waters.

The pontoons (see Plate X) are made of flat sheet iron rivetted to a framework of ∠ iron; they are about 24 feet 6 inches long, and have a boat-shaped bow, while the stern is square, so that two of these bateaux may be coupled together by the sterns to form one long boat 49 feet long. The transverse section of the bateau is peculiar; the bottom is about 3 feet 6 inches wide, the sides incline outwards from the bottom at an angle of 45°, until the width of the pontoon is 5 feet 9 inches, when they incline inwards, until, at the gunwale, the width is reduced to 4 feet 9 inches; the depth of the pontoon is 2 feet 7½ inches, the weight 1,212 lbs., and the buoyancy 18,584 lbs. When a bridge is formed for ordinary loads the pontoons are employed singly, and give a power of 580 lbs. per lineal foot of the roadway. It was originally intended that the supports for the bridges for extraordinary loads should be formed by coupling together by the sterns two of the bateaux, but this arrangement has been found not to answer, on account of the weakness of the pontoons, and also of their junctions; and the two parts of the pontoon are now placed side by side, which is even a worse method of obtaining the additional buoyancy than that of bringing the bateaux closer together. By either of the methods adverted to, the power of the Belgian bridge is raised to 1,244 lbs. per lineal foot, which is about 20 per cent. more than is required theoretically.

As in the Austrian equipment, the great length of the two-part Belgian pontoons allows the construction of two or three roadways, which might be of great advantage in passing an army over a narrow stream. This great length also admits of the formation of large rafts, which can be very easily rowed through the water on account of the shape of the bow being well adapted for this purpose. The bateaux, being open, are very suitable for ferrying troops over a river, one bateau being capable of containing 36 men in heavy marching order.

The objects sought in the peculiar section adopted in the Belgian pontoons appear to be that their greatest width, and, consequently, their maximum stability, should come into play when they are submerged to the depth due to the average load which may be expected on service, while the diminished width of the top of the vessels allows a reduction in the length of the baulks, which are laid with double bearings or restings on both gunwales of the pontoons.

The Belgian trestles are of very ingenious construction, and deserve to be more brought into notice on account of the facility with which temporary trestles upon the same principle may be constructed of almost any kind of rough material. (See Plate X.)

They consist of a strong ridge, beam or transom, held up at each end by a yoke supported on two of the legs of a tripod. The tripods

are so constructed, and when placed in bridge are so adjusted, that the feet of two of the legs are in a direction parallel to the sides of the bridge, while the legs themselves are in a nearly vertical plane; the third leg or tripod being about midway between the other two and inclining towards the bridge, thus forming a buttress. The heads of the three legs are pierced with holes at various distances, so that by simply adjusting the connecting pin into one or the other of these holes, the trestle may be arranged to suit any inequality of the ground upon which it may be placed. The feet of the legs are connected together by iron rods. The yokes which support the transom are formed of two pieces of wood, secured together at such an interval as to admit free passage up and down the legs of the tripod. These legs are pierced at intervals of 4 inches with holes, through which are placed iron pins, on which the yoke may be securely fixed at any required height.

This method of supporting the transom affords great facility for raising and lowering the roadway in order to suit any change in the level of the water, or to adjust any irregularities caused by the unequal settlement of the trestles. The details of the operation of raising or lowering the transoms, being so simple that four men can with readiness alter it to the adjustments required at each end of a bridge constructed on a river with a tidal fluctuation of 15 feet, which is about the limit of the application of these trestles in a single tier.

These adjustments can be effected without interruption to the passage of the troops.

The baulks for the pontoons of this equipment are laid with double bearings, and as the intervals between the centres of pontoons are rather large, being about 20 feet, the baulks are obliged to be of considerable length, 26 feet 3 inches. The intervals between the transoms of the trestles are the same as those between the centres of the pontoons, viz., 19 feet 8 inches; but it is only necessary that the baulks should cross on the ridge of the trestles, so that they are only 22 feet 0 inches, thus requiring two descriptions of baulks, which to a certain extent complicate the material.

Both kinds of baulks are made of the same section, but the bearing in the case of the pontoons is 14 feet 11 inches, when five baulks are sufficient, but with the trestles it is 19 feet 8 inches, and here seven baulks are required, and this to a certain extent complicates the exercise.

Bridges made with the Belgian pontoons are very stable on account of their length and breadth at the water line, which is such, that when the roadway is raised some feet by means of the trestles supported only by the one part pontoons, the motion due to the unequal action of the load is inconsiderable in smooth water.

The superstructure of one bay of the bridge with either a bateau or a trestle is packed on one waggon, weighing when loaded, 4,500 lbs., and drawn by 6 horses, and so constructed that when drawn by the wheelers alone it is capable of being turned in 35 feet.

As before alluded to, the square stern of these demi-bateaux has been found to be so great a disadvantage in tidal rivers that it is probable

that the Belgians will give to the stern the same form as the bow, thus coming round again to the old bateau form of vessel. In the Belgian pontoons, 6·54 per cent. of the buoyancy is required for their own support.

The progress of the art of pontoon-making in Italy, would be very instructive if we could but trace it in consecutive order. It appears probable that the Italians were the first who divided their pontoons into three parts as is now done by the Austrians, and as North Italy has always been one of the chief, if not the chief battle field of the world, and is much intersected with rivers both wide and rapid, it is reasonable to suppose that troops defending such a country would give much attention to the study of the best means of crossing the rivers and streams.

In the early part of this century the Italians used demi-bateaux of wood, very similar to those which were employed in Austria before Birago introduced the system now adopted. In 1833 General Cavalli introduced an equipment still retaining the demi-bateau form, but making them 19 feet 6 inches long, the weight being 990 lbs., and the buoyancy 17,660 lbs., or about the same as that of one prow and half a middle piece of the Birago pontoons. Cavalli's intention was that these demi-bateaux singly should serve as the support of the normal bridge, while for extraordinary loads two would be coupled together by the sterns. The pontoons were placed in bridge at intervals of 26 feet 3 inches, and the prow of the bridge formed with single demi-bateaux was 402 lbs. per foot, and with two coupled together 878 lbs. Finding that these bridges were not of sufficient power, the length of the demi-bateaux was increased in the year 1860 to 24 feet 6 inches, and the interval in bridge was reduced to 23 feet, the powers of the bridges being thus augmented to 551 lbs. and 1,178 lbs.; these are now the authorized pontoons of the Sardinian Service.

The baulks of Cavalli's first equipment, which were 26 feet 3 inches long, were formed in two pieces, joined together by an iron hinge, so constructed that when opened out, the two parts formed a rigid beam. It was almost impossible to make and keep all the hinges perfectly similar in action, without which, each of the baulks would not bear its due proportion of the load, and in the new equipment this idea has been abandoned, and the baulks are now made in one piece 23 feet long. The baulks of the two adjacent bays are placed with the ends butting against each other and resting on an oak transom which lies across the pontoon, and is furnished with two pins, each about 6 inches from the middle, which pass into holes in the baulks, and thus keep the pontoons at the proper intervals; by this arrangement the baulks rest over one of the gunwales of the pontoon, and when the adjoining portion is deeply immersed during the passage of a load, the end of the baulk which is over the middle of the pontoon, rises and brings a strain upon the planks of the roadway of the bridge, the surface of which it disarranges to some extent.

The bateaux and superstructure for two bays are carried on three waggons, the chesses for both bays being on one waggon, which is given up entirely to their transport. The weight of the loaded waggons

is about 4,400 lbs., and they are drawn by 4 horses. The bateaux are conveyed on the waggons with the gunwale upwards, and with all the stores, anchors, cables, packed in them ready for use, and they are moved on and off the waggons in the same condition, but they are very heavy, weighing 1,800 lbs., and the straight part of the bottom, at which only the men can apply their strength is limited, so that the operation is both difficult and slow.

The stability of the pontoons is about the same as that of the Belgian.

The Sardinians have found that their own equipment is not sufficiently mobile to accompany an ărmy in very rapid movements, and they have therefore a certain quantity of material of the Birago pattern, in which they have retained the plan of connecting the baulks to the pontoons and trestles by notches instead of by pins, as in their own system.

6·3 per cent. of their buoyancy is required to support these pontoons.

In Prussia the pontooneers appear to have followed in the track of the Austrians until late years, when up to 1856 their established pattern was a wooden bateau with a boat shape at the bow and stern, the length being 23 feet 8 inches, the depth 2 feet 6 inches, and the breadth 5 feet; the weight 1,134 lbs., and the buoyancy 10,226 lbs.

The intervals at which these bateaux were placed in bridge varied according to the nature of the load for which the bridge was constructed, being 15 feet 4 inches for ordinary loads, 13 feet 3 inches for field artillery, and 11 feet 2 inches for extraordinary loads, the powers of the bridges being 384 lbs., 448 lbs., and 535 lbs. respectively. Bridges of this character were found to be inadequate to the wants of an army, and an iron vessel of the same form has been introduced, but all the dimensions are increased, so that the powers of the bridges are now 561 lbs., 637 lbs., and 759 lbs.

One pontoon and the superstructure for one bay of the normal bridge is carried on one waggon, which, when loaded, weighs about 4,500 lbs., and is drawn by 6 horses, and it is so constructed, as to be reversible in about 25 feet when the wheel horses only are attached. The Prussians however consider that this equipment from its want of mobility, is only suited for the general purposes of an army, and they adopt the Birago equipment when rapidity of movement is desirable

The proportion of buoyancy required to support the pontoons is 7·1 per cent.

The transverse section of the Prussian pontoon is a segment of an elipse, cut off by a line parallel to the major axis, and about half the length of the minor axis above the centre. This form of section causes the pontoons to roll very easily when used as boats, but is supposed to reduce the obstruction to the current.

Upon this point some very interesting experiments were tried in Prussia, with the view of ascertaining the relative pressure exerted by a current of 4 miles per hour upon wood and iron pontoons of precisely similar form, and the results were,

When empty, the pressure upon the	wooden pontoon was	50	lbs.
" "	iron "	35	"
When loaded within 9 ins. of the gunwale	wooden "	150	"
" "	iron "	90	"

The Prussian pontoons have not sufficient buoyancy to support bridges for all the wants of an army, without interfering to a dangerous extent with the current of the river.

The trains are not sufficiently mobile to accompany an army moving with rapidity.

The Russians have had in use, since 1755, a pontoon of very ingenious construction, consisting of a sheet of canvas stretched over a skeleton of wood, which can be taken to pieces for transport, the two sides of the skeletons are flat frames, kept apart by transoms at the top and bottom, and tied together by ropes used as tourniquets. The covering is simply a sheet of waterproof canvas, which is stretched over the framework by hand, and secured to the gunwale by iron nails. To prevent the canvas from bending inwards between the transoms, two ropes pass from end to end of the pontoon below the transoms and inside the canvas.

These pontoons are 21 feet long, 5 feet 3 inches wide, and 2 feet 4 inches deep, their weight is 715 lbs., and the total displacement due to the outline is 13,042 lbs., this however, practically, is considerably reduced, owing to the concavities caused by the pressure of the water.

The pontoons were placed in bridge at intervals varying according to the load expected, the greatest interval being 16 feet 8 inches, the least 11 feet 8 inches, and the intermediate 14 feet 2 inches, the power of the bridges so formed being 493 lbs., 573 lbs., and 705 lbs.

Unloading, putting together, and launching a pontoon occupies about 5 minutes.

The baulks, of which there are five to each bay, are laid with double bearings, but are not secured in any way to the pontoons, each pair being connected together by iron pins passing through holes bored in the baulks, in such positions as to secure the proper intervals between the bateaux.

Each canvas bateau, and the baulks and chesses required for one bay, are carried on one waggon, which, when loaded, weighs about 3,780 lbs., and is drawn by 6 horses; the waggon and load can be reversed in 38 feet.

The proportion of buoyancy expended in the support of these pontoons is about 9·168 per cent., allowing for a loss of one eighth of the buoyancy of form, by the cavities in the canvas.

Besides the canvas pontoons, the Russians make use of the Birago pontoons, and from a conversation with General Todleben, I have learned, that it is now decided to abandon the old canvas pontoon, and to adopt an equipment somewhat similar to that proposed by Birago—the chief objection assigned to the canvas vessels being, that they are so frequently out of repair at the time they are required for forming bridges.

In the war with the Indians in Florida, the pontooneers of the United States army formed an equipment of india-rubber pontoons, concerning which, there has been much discussion as to whether they were invented in this country or in the States. They consist of three long air-tight bags, each of which, when inflated, forms a cylinder 20 feet long and 1 foot 8 inches in diameter, and is sub-divided into three air-tight com-

partments. These three cylinders, when inflated, are connected together laterally, forming a float 20 feet long, 5 feet wide, and 1 foot 8 inches deep; their buoyancy being 8,125 lbs., and the weight 420 lbs.—the per centage of weight to buoyancy being 5·175 lbs.

These pontoons have been tried in various countries besides the United States, and although their utility as an adjunct to a bridge train is almost universally acknowledged, it is equally decided that they are not to be trusted as the sole means of support of a bridge train.

One great disadvantage of this nature of pontoon is, that its buoyancy depends entirely on the envelope being completely air-proof, a condition which is very difficult to ensure during the vicissitudes of a campaign. That this equipment cannot be recommended, is very conclusively shewn by the fact that, in the present campaigns it is not employed by the Americans, who have fallen back upon the wooden bateau of the French army.

The report on these pontoons by General Bernard, the Chief Engineer of the Washington army, is well worthy of attention. After speaking generally of the evils growing out of the want of properly organised engineering service in the Northern army, he adverts to the bridge equipments and says, that the pontooneers, "after full consideration of "the subject, give their preference to the French system; even had they "adopted this system blindly because it was French, they would not "have been without solid reasons, for the French have studied and "experimented upon the best systems known to the world. Whatever "may be said about the differences in the characters of the country, "roads, &c., the thing to be done here and in Europe (now that our "armies have assumed European magnitudes) is essentially the same.

"But these officers had before them the best modern inventions "of Europe and America. The india-rubber pontoons they knew "thoroughly; corrugated iron bodies, and countless other inventions of "American genius were before them, and the former experimented "upon.

"My own propositions have been in favour of the Birago system of "sectional pontoons and Birago trestles.

"The experience we had, proved the wisdom which had adopted the "system in question—not to advance by any means, that nothing "better can be found, (the substitution of iron for wood was one of the "probable improvements well understood by the officers named, but not "at the time adopted for substantial reasons), it is enough to say, that "the French pontoon was found to be most excellent, useful, and "reliable for all military purposes. They were used by the Quarter-"Master-General's Department in discharging transports; were precisely "what was needed for the disembarkation of General Franklyn's division; "constituted a portion of the numerous bridges over Wormly Creek "during the siege of Yorktown, and were of the highest use on "the Chickahominy, while over the lower Chickahominy some 75,000 "men, some 300 pieces of artillery, and immense baggage trains passed "over a bridge of the extraordinary length of 650 yards.

"The Birago trestle, of which I had formed so high an opinion, found "itself dangerous and unreliable—useful for an advanced guard or a

"detachment—unfit in general for a military bridge. Of the American
"india-rubber and Russian canvas pontoons we had no fair experience.
"They may both be useful, but again I think not reliable for a military
"bridge considered in all its aspects and uses.

"The weight of the French pontoon is objected to, but *a certain
"floatation power is required*, which it is not easy to get, nor are the
"wings unobjectionable which seek to get it at less weight; and the
"vehicle which carries it is not heavier loaded than other vehicles of an
"army train. *Less length* would certainly make it more managable on
"our narrow roads, while for advanced guards and dashing minor enter-
"prises, greater lightness is requisite.

"Perhaps an iron sectional pontoon may be contrived which will meet
"these requirements, but prudence demands that the safety of an army
"shall not be jeopardised, by giving it a bridge which experiment has
"not fully tested. American genius is fertile in this as in all other
"expedients, but no genius can provide for an object which is not
"understood.

"The numerous proposers of flying bridges forget that if a military
"bridge is intended to be carried it is also intended to carry an army,
"its columns of men, its cavalry, its countless waggons, its ponderous
"artillery. It must carry all these things, and it must do it with
"certainty and safety, even though a demoralised corps should rush
"upon it in throngs.

"No make-shift expedient, no ingenious inventions not tested by
"severe experiment, nor light affair of which the chief merit alleged is
"that it is light, will be likely to do what is required, and what the
"French pontoon has so often done."

This report, in General Bernard's own words, is useful, as showing the value placed after trial upon the Birago trestles and light equipments, and as showing the value which he, in America, placed upon an equipment, which in Europe the French themselves are now finding inadequate to the work of European armies, and as showing what a high standard of efficiency is required for a bridge equipment for armies working in the field in these days.

We may now turn to the English equipments and see what state our own material is in, and what chance our own pontooneers would have of carrying out satisfactorily their *rôle* in a campaign.

The old English pontoon which was used by the British army in the Peninsular War, was of almost the same pattern as those which had been employed by Continental Nations in the middle of the 18th century, and having been found thoroughly inefficient, had by them been replaced by others of double, and in some cases, of more than double their capacity. According to Sir Howard Douglas, these pontoons or bateaux were made of a wooden framework, covered on the outside and lined on the inside with tin, the sides, bottom, and ends being double, to give security against leakage, and also to form water-tight compartments to prevent the pontoons from sinking if filled with water. In plan the pontoons were rectangular, the bottom was flat, the sides rose perpendicularly from it, the ends had an inclination of 45°. The length was 21 feet, the breadth 4 feet 10 inches, and the depth 2 feet 10 inches.

the weight 1,050 lbs., and the buoyancy 13,092 lbs. They were given up on account of their unwieldiness, their liability to be submerged, (consequent upon the shortness of their floor,) and the great obstruction which was opposed to the current by bridges constructed with them. On the continent they were succeeded by the open or bateau form, but in the English army in 1814, Sir James Colleton, who had witnessed several failures of the old English pontoon, conceived the idea of using closed vessels of a very ingenious design, which had the advantage of being cheap and light, and at the same of much simpler construction, that they could be made by moderately skilled workmen. The General's idea, was a cylinder closed at the ends with cones, the whole being formed of staves somewhat similar to those of a barrel, and drawn together by means of iron hoops keyed on both sides, and they were then coated with mineral tar. These buoys were proposed to be used in pairs yoked together with a small interval between them, so as to form a small raft to be employed instead of one of the old pontoons. Sir James Colleton proposed many modifications of this plan, but upon trial they were set aside.

The late General Sir Charles Pasley gave much attention to the subject of pontoons, and produced a system upon which he was engaged at the time of his death. Each of the supporting bodies of his equipment consists of two demi-bateaux or canoes, coupled together by the stern; they are made of copper sheathing upon a framework of wood or copper, and are closed above by a wooden deck, the transverse section being a rectangle 2 feet 9 inches wide, and 2 feet 5 inches deep, the lower angles being rounded off, the bows or bow and stern are similar to the bow of a boat; the demi-canoes are connected together by rope lashings, which above, are rove through eye-bolts in the deck, and below, through holes cut in the keels. The baulks rest on and are pinned to gunwale pieces, which tie on each side of the deck and are secured to it by rope lashings.

The gunwales have not sufficient strength to resist the action of the load upon them without bending, and consequently a great strain is thrown upon the keel lashings, which therefore break, or tear away a part of the keel.

The interval at which the canoes were placed in bridge was 12 feet 6 inches, and the bridge has then a power equal to 481 lbs. per lineal foot of roadway.

Each pair of demi-bateaux and the superstructure for one bay is carried on a two-wheeled cart, which, when loaded, weighs 3,110 lbs., and is supposed to be drawn by two horses, and could be turned in a space of 26 feet 3 inches, The percentage of weight of pontoons to buoyancy is 9·3.

This equipment, and that of General Colleton, was tried against that proposed by the late General Blanshard, which was selected in preference, and still continues the authorized pontoon of the service.

General Blanshard's pontoons consist of a cylinder of tin with hemispherical ends, the length being 22 feet 4 inches, and the diameter 2 feet 8 inches, the weight of one cylinder is 464 lbs., and the displacement 6,785 lbs. Before these cylinders can be used for the

support of the baulks it is necessary to lash upon them a saddle which weighs 90 lbs., the percentage of weight to buoyancy being then 8·7.

The interval in bridge varies with the nature of the load expected, that at close order being 8 feet 4 inches, at intermediate order 10 feet 5 inches, and at open order 12 feet 6 inches, the power of the bridge being 581 lbs., 476 lbs., and 373 lbs. Two cylinders and two sets of superstructure are carried on one waggon, weighing 4,800 lbs., and intended to be drawn by four horses.

Experiments were made with demi-pontoons of this form made of copper, but they were found not to answer; but lately they have been tried again made of iron, and I have been informed are now introduced into the service.

Corrugated iron has been proposed as a material for the construction of these pontoons, but without success.

Bridges formed with Blanshard's pontoons having been found unstable and lively under passing loads, Mr. Forbes, late of the Royal Sappers and Miners, proposed to remedy these defects, by giving to the pontoons a triangular section of about the same area, the sides of the triangles being arcs of circles. This form of section increased the weight of the pontoon, but as they were placed in bridges with one of the angles downwards, a continually increasing area of bearing surface was obtained nearly up to the safe immersion of the pontoon. It was also imagined that this form of bow and section would reduce the pressure of the current above the bridge. On trial it was found that the liability to injury at the angles counterbalanced all other advantages, and the pontoon was not recommended.

Captain Fowke, of the Royal Engineers, brought forward a very ingenious kind of pontoon, based upon the idea of a flexible covering distended at intervals by an internal frame-work, and so arranged that for transport it could be collapsed like the bellows of an accordion, and when required for bridge making could be distended longitudinally by means of long beams or transoms. Captain Fowke has constructed these vessels of various forms and dimensions, the last having somewhat the form of a flat-bottomed open boat, of which the ends were decked over with canvas, and the body part is also partially covered with the same material, a narrow hatchway being left down the middle for convenience of baling out and examining the interior, and also to admit of the pontoon being used as a boat. The weight of the pontoon and its stretchers is 496 lbs., and the buoyancy due to its outline form should be 13,594 lbs., but is found to be reduced to 8,456 lbs., in consequence of the indentations in the surface formed by the pressure of the water upon the canvas between the ribs.

It is proposed that these vessels should be placed in bridge at intervals of 10 feet, the power of the bridge being then 541 lbs., the percentage of the buoyancy of these pontoons taken up by their weight is 5·9 lbs.

By experiment it has been found, that the irregularities of the surface of these pontoons caused the resistance to the current to be three times that opposed by a bridge of the same power supported upon Pasley's or Blanshard's pontoons, which have rigid and smooth sur-

faces; and the risk of the bridge being carried away in strong currents would prevent the adoption of these vessels for the general purposes of an army, although they would probably be very useful in desultory operations.

On an inspection of the dimensions of all the pontoons of the English equipments, it will be noticed that they are all very similar, leading to the conclusion that one of them having been proposed originally as a new invention, and that the proposers of the others have been merely endeavouring to improve the form and details, but have not considered whether the principle is sound or not. Blanshard's pontoons, which may be taken as the type of vessels of these small dimensions, have been tried by many of the continental nations, but have not been adopted on account of their not offering sufficient advantages over those in use.

Small closed vessels were much used at one time on the continent. They were originally introduced by the Dutch, and were made of tin, copper, or wood; but the great disadvantage of their not being applicable to the transport of troops led to their being abandoned.

Having thus given you, in the first place, and as concisely as lays in my power, a short statement of the many and varied conditions required in a bridge train; and having passed rapidly in review some of the equipments which of late have been used or proposed for the service of our own and continental armies, I will take leave of the subject, hoping that the few words I have said may induce some inventor's mind to bring forward a pontoon equipment which, besides possessing all the conditions requisite for the construction of bridges adequate to the support of an army under any of the circumstances of war, shall at the same time have sufficient mobility to allow of its always being at the spot required.

The Chairman: From the great practice that Colonel Lovell has had in pontooning, from his study of the subject, and the numerous researches that he has made in various countries on them, I am sure there is no person more capable of dealing with the subject than he is; and I am satisfied that I am not wrong in conveying to him the thanks of this meeting for the mass of information contained in his interesting lecture.

APPENDIX.

Description of the Table.

The first three columns show the length, breadth, and depth of the pontoons; the fourth and fifth give the displacement in cubic feet and lbs.; the modern figures in the sixth column, give the weight of the pontoon alone, and the ancient figures show the entire weight of the pontoon and those fitments without which it cannot be used as the support of a bridge; the seventh column shows the weight of one bay of superstructure as accurately as it could be obtained from the sources of information available; the eighth column gives the total power of support of each pontoon, or the buoyancy remaining after deducting the weight of the pontoon and one bay of superstructure from the total displacement; the ninth column gives the power of support available for the load which is obtained by allowing a surplus buoyancy of $\frac{1}{4}$ of the total power for open pontoons, and $\frac{1}{10}$ in closed vessels; at column 10 is shown the interval at which the pontoons are placed in bridge; and at column 11 is the power of the bridge per lineal foot of roadway, obtained by dividing the figures in column nine by those in column 10; in columns 12 and 13 are shown the greatest extraordinary and ordinary loads which may be expected on the bridge, the former being that of unarmed men crowded on the roadway, the width of which is shown at column 14, and the latter that of infantry in heavy marching order moving in fours, and supposed to have become crowded in consequence of a check on the bridge; at column 15 is shown the weight of the pontoon and its fitments divided by its total capacity, or the weight of the pontoon per cubic feet of displacement; at columns 18 and 19 are shown the intervals at which it would be necessary that the pontoons should be placed in order to support the standard loads of 560 lbs. per lineal foot and 110 lbs. on each square foot of surface of the roadway, but as the width of the roadways varied in the different systems, a comparison of the loads on them would not have been fair, and a standard width of 10 feet has been adopted in these calculations, although it is not intended to specify that as the proper width of the roadway; at columns 16 and 17 are shown approximately the areas per lineal foot of bridge of the transverse sections immersed when the bridges are arranged for the support of the standard loads. These areas have been found by dividing the displacement under those loads by the mean length of the immersed portion of the pontoons and by their intervals in bridge.

COMPARATIVE TABLE of various PONTOONS, showing the POWERS of the BRIDGES
be necessary to place the Pontoons to support the standard Loads of 560 lbs. per

	DESCRIPTION OF PONTOONS.	I. Total length of Pontoon over all.	II. Width of pontoon, greatest section.	III. Depth of Pontoon midship.	IV. Displacement of Pontoon.
		Feet.	Feet.	Feet.	Cu. ft.
1	Gribeauval; oak; found efficient, but too heavy for transport	36·29	6·74	3·81	592·7
2	Austrian model, wood; in general use 1799; failed three times from want of power; burnt in retreat from Russia	26·97	6·23	2·59	353·97
3	Do. Birago; original pattern wood; open; two bow pieces	28·00	6·14	2·42	302·51
4	Do. do. do. do. one bow and one middle piece	25·4	6·14	2·42	293·41
5	Do. do. do. do. two bows and one middle piece	39·4	6·14	2·42	444·66
6	Do. do. present pattern iron; open; two bow pieces	28·00	6·22	2·59	353·44
7	Do. do. do. do. one bow and one middle piece	25·41	6·22	2·59	353·44
8	Do. do. do. do. two bows and one middle piece	39·41	6·22	2·59	530·16
9	Belgian; open iron boat; square stern, boat-shaped bow; one piece	24·8	5·75	2·56	297·35
10	Do. do. do. do. two pieces, stern to stern	49·6	5·75	2·56	594·70
11	Italian, Cavalli; original pattern wood; stern square, bow boat-shaped; one piece ...	19·6	5·77	2·95	282·56
12	Do. do. do, do. two pieces side by side	19·6	11·54	2·95	565·12
13	Do. do. do. do. two pieces end to end	39·2	5·77	2·95	282·56
14	Do. modified pattern do. do. one piece...	24·6	5·77	2·82	324·64
15	Do. do. do. do. two pieces side by side	24·6	11·54	2·82	649·28
16	Do. do. do. do. two pieces end to end	49·2	5·77	2·82	324·64
17	French reserve pattern till 1853; open wooden bateau; fir	30·93	5·06	2·58	324·58
18	Do. advanced guard pattern till 1853; open wooden bateau	19·69	4·59	2·30	155·74
19	Do. present general pattern; open wooden bateau	30·93	5·06	2·58	321·04
20	Prussian; old pattern wood open boat, both ends boat-shaped; open order	23·69	5·06	2·49	163·62
21	Do. do. do. do. intermediate order ...	23·69	5·06	2·49	163·62
22	Do do. do. do. close order	23·69	5·06	2·49	163·62
23	Do. new pattern iron do. do. open order	24·71	5·15	2·75	214·16
24	Do. do. do. do. intermediate order ...	24·71	5·15	2·75	214.16
25	Do. do. do. do. close order	24·71	5·15	2·75	214·16
26	Russian open canvas... ... ... open order	...	...	...	...
27	Do. wooden framework which takes two pieces ... ... common order ...	21·0	5·25	4·33	208·66
28	... ... close order	...	...	...	...
29	Dutch; open boat in two pieces; wood; common order	26·25	5·25	2·63	225·79
30	Do. do. do. open order	26·25	5·25	2·63	225·79
31	Do. do. do. close order	26·25	5·25	2·63	225·79
32	American; inflated india-rubber; three cylinders connected; open order	20·0	5·0	1·66	130
33	Do. do. do. do. close order	20·0	5·0	1·66	130
34	English peninsular reserve equipment; open tin bateau, double sides and bottom ...	21·08 / 16·67	4·83	2·29	209·47
35	Do. do. advanced guard do. do. ...	16·83 / 13·33	4·0	2·0	120·33
36	Do. Colleton buoy pontoon; cylindrical, with conical ends made like a cask; wood	...	...	...	173
37	Do. Pasley; copper demi canvas with wood deck	25·0	2·75	2·58	140·5
38	Do. Blanshard; cylinder tin; hemispherical ends; open order	22·5	2·66	...	108·56
39	Do. do. do. do. intermediate order	22·5	2·66	...	108·56
40	Do. do. do. do. close order	22·5	2·66	...	108·56
41	Do. do. do. conical ends; infantry pattern...	15·5	Diar. 1·58	...	26·25
42	Do. Fowke's pattern; collapsible canvas...	22·0	5·25	2·66	133·60
43	Do. Forbes' spherangular tin	24·166	2·77	2·84	127·6

formed according to the established Systems, and the Intervals at which it would lineal foot of Bridge, and 110 lbs. per square foot of a Roadway 10 feet wide.

V. Displacement of Pontoon.	VI. Weight of Pontoon.	VII. Weight of one bay of superstructure.	VIII. Power of support, total lbs.	IX. Power of support for loads, $\frac{3}{4}$ for open Pontoons, $\frac{8}{10}$ for close Pontoons.	X. Interval in Bridge.	XI. Power per lineal foot of roadway.	XII. Greatest possible load at 110 lbs. per foot superficial.	XIII. Greatest ordinary load, 560 lbs. per foot lineal.	XIV. Width of roadway.	Width of Pontoon and fitments per cubic foot of displacement.	Area of greatest immersed transverse section, roadway 10 feet wide. Load per lineal foot. lbs. 1,100.	Area of greatest immersed transverse section, roadway 10 feet wide. Load per lineal foot. lbs. 560	Interval at which the Pontoons should be placed to support. Load per lineal foot. lbs. 1,100.	Interval at which the Pontoons should be placed to support. Load per lineal foot. lbs. 560.
lbs.	lbs.	lbs.	lbs.	lbs.	Feet.	lbs.	lbs.	lbs.	Feet.					
45,044	4,075	3,969	37,000	27,750	22·8	1,215	1,716	560	15·6	6·70	...	...	...	...
22,123	1,540	1,792	18,791	14,093	16·6	849	1,254	560	11·41	4·35	·968	·510	13·031	24·898
18,907	{1,515 / 1,280}	1,969	15,658	11,744	21·67	542	1,026	560	9·33	5·00	·938	·494	11·02	21·055
18,338	{1,512 / 1,277}	1,969	15,092	11,319	21·67	522	1,026	560	9·33	5·15	·981	·517	10·646	20·34
27,791	{2,295 / 1,915}	1,969	23,907	17,930	21·67	827	1,026	560	9·33	5·16	·613	·323	16.481	31.489
22,090	{1,964 / 1,729}	1,969	18,392	13,794	21·67	636	1,026	560	9·33	5·55	·943	·497	12·76	24·34
22,090	{1,902 / 1,667}	1,969	18,454	13,841	21·67	639	1,026	560	9·33	5·38	·945	·498	12·87	24·59
33,135	{2,912 / 2,532}	1,969	28,634	21,476	21·67	991	1,026	560	9·33	5·49	·615	·322	19·61	37·46
18,584	1,212	2,124	15,248	11,436	19·69	580	1,045	560	9·5	4·09	·954	·508	10·79	20·62
37,168	2,424	2,124	32,620	24,465	19·69	1,244	1,045	560	9·5	4·09	·462	·242	22·29	42·59
17,660	{1,107 / 990}	2,592	14,078	10,559	26·25	402	1,082	560	9·84	3·91	1·369	·721	10·125	19·345
35,320	{2,097 / 1,980}	2,592	30,748	23,061	26·25	878	1,082	560	9·84	3·71	1·294	·688	21·16	40·128
35,320	{2,907 / 1,980}	2,592	30,748	23,061	26·25	878	1,082	560	9·84	3·71	·647	·344	21·16	40·128
20,290	{1,305 / 1,188}	2,133	16,889	12,669	22·97	551	1,082	560	9·84	4·01	1·001	·528	12·02	22·967
40,580	{2,493 / 2,376}	2,133	36,091	27,068	22·97	1,178	1,082	560	9·84	3·84	·982	·518	22·017	42·067
40,580	2,376	2,133	36,091	27,068	22·97	1,178	1,082	560	9·84	3·84	·496	·259	22·017	42·067
20,286	1,654	1,934	16,678	12,509	19·69	635	1,159	560	10·54	5·09	·923	·487	11·77	22·49
9,734	650	856	8,228	6,171	16·41	376	1,026	560	9·33	4·17	...	...	...	...
20,065	1,323	1,830	16,912	12,684	19·69	644	1,082	560	9·84	4·12	·898	·472	11·916	22·762
10,226	1,134	1,259	7,833	5,875	15·30	384	1,093	560	9·94	6·93	1·191	·627	5·681	10·854
10,226	1,134	1,169	7,923	5,943	13·26	448	1,093	560	9·94	6 93	1·191	·627	5·681	10·854
10,266	1,134	1,079	8,013	6,010	11·22	535	1,093	560	9·94	6·93	1·191	·627	5·681	10·854
13,385	959	1,250	11,176	8,382	15·30	561	1,093	560	9·94	4·47	1·05	·554	7·88	15·07
13,385	959	1,160	11,266	8,450	13·26	637	1,093	560	9·94	4·47	1·05	·554	7·88	15·07
13,385	959	1,070	11,356	8,517	11·22	759	1,093	560	9·94	4·47	1·05	·554	7·88	15·07
...	959	1,640	10,687	8,015	16·625	493	1,140	560	10·371	...	...	...	...	...
13,042	715	1,504	10,823	8,117	14·15	573	1,140	560	10·371	...	1·172	·611	7·68	14·68
...	...	1,368	10,959	8,219	11·66	705	1,140	560	10·371	...	...	...	...	...
14,112	1,363	1,969	10,780	8,085	21·33	379	1,082	560	9·84	...	...	...	7·9614	15·211
14,112	1,363	2,203	10,546	7,910	26·25	301	1,082	560	9·84	6·02	...	...	...	...
14,112	1,363	1,579	11,170	8,378	13·13	637	1,082	560	9·34	...	1·164	·591	...	...
8,125	420	1,560	6,141	5,530	18·0	307	1,210	560	11·0	2·00	...	...	5·635	10.710
8,125	470	1,404	6,401	5,761	16·66	393	1,210	560	11·0	2·00	...	...	5·635	10·710
13,092	1,050	1,324	10,718	8,039	16·83	477	1,100	560	10·0	5 03	1·176	·62	7·61	14·55
7,520	772	882	5,866	4,400	14·0	314	990	560	9·0	6·41	1·571	·823	4·18	7·98
...	594	...	...	...	...	...	...	...	...	3·43	...	...	...	...
8,781	{818 / 778}	1,325	6,678	6,010	12·5	481	1,100	560	10·0	5·83	·956	·513	5·866	10·955
6,785	{590 / 482}	1,120	5,185	4,667	12·5	373	1,100	560	10·0	5·43	1·026	·541	4·548	8·643
6,785	482	1,023	5,280	4,752	10·42	456	1,100	560	10·0	5·43	...	...	...	...
6,785	482	926	5,377	4,839	8·33	581	1,100	560	10·0	5·43	...	...	...	...
1,640	140	200	1,300	1,170	5·33	220	...	...	7·0	5·33	...	...	...	...
8,460	496	750	7,214	5,411	10·0	541	1,100	560	10 0	3·55	1·615	·846	5·077	9·702
7,977	672	1,024	6,288	5,659	11·0	514	1,100	560	10·0	5·26	...	...	...	...

Evening Meeting.

Monday, January 16, 1865.

His Grace the DUKE OF SOMERSET, K.G., First Lord of the Admiralty, and Vice Patron of the Institution, in the Chair.

NAMES of MEMBERS who joined the Institution between the 1st and 16th January, 1865.

LIFE.

Ross, J. T. C., F.R.C.S., Surgeon, 21st Hussars. 9*l*.
Tryon, Thomas, Colonel late 7th Royal Fus. 9*l*.

ANNUAL.

Le Patourel, H., Lieut. South Glo. Mil.
Shoubridge, H. W., Lieut. H. M. Ben. Army.
Vandeleur, T. B., Capt. 7th Roy. Fus. 1*l*.
Fyers, W. A., Lieut.-Col. Rifle Brigade. 1*l*.
Faucett, R. H., Lieut. 33rd Regt. 1*l*.
Buchanan D. C. R. Carrick, Lieut.-Col. 2nd Royal Lanark Militia. 1*l*.
Taplin, Thomas, Surgeon late H. M. Madras Army. 1*l*.
Brydon, L. A., Capt. late 74th Highldrs.
Folch, S. V., Lieut. 3rd West York Mil. 1*l*.
Dawson, G. A., Lieut. 23rd Roy. W. Fus.
Rowley, G. C. E., Ens. 23rd Roy. W. Fus.
Van Straubenzee, T., Capt. Roy. Art. 1*l*.

PETROLEUM AS STEAM FUEL.

By Captain Jasper H. Selwyn, R.N.

There is no question but that, in the future as in the past, the greatness of England as a Power must mainly depend on the thorough efficiency of her Navy.

At no former time have there been so many causes in operation to

enable other countries to compete, on favorable terms, with her who has so long been called Mistress of the Seas. Therefore it is the more necessary that every change in the materials available, which may influence our naval future, should be closely investigated, and either be at once pursued to its legitimate conclusion, or rejected from our consideration. One of the most important possible would be a new fuel.

Among the many new gifts of Divine Providence which come from time to time in the shape of inventions or discoveries, to alleviate the sorrows or increase the blessings of the human race, there has been none within modern recollection which is more calculated to be felt by rich and poor alike than the utilization—I shall presently show that it is not a discovery—of petroleum, or so-called mineral oil, from whatever source it is derived.

In the 1st chapter of the 2nd book of Maccabees, in the Apocrypha, will be found a full description of the discovery of a substance which was evidently no other than the oil in question, and to which the name of "*napthar*," is there given.

A Letter of the Jews from Jerusalem to them of Antioch, B. C. 144.

Maccabees, 2nd Book, 1st Chapter, 19th verse.

For when our fathers were led into Persia, the priests that were then devout took the fire of the altar privily and hid it in a hollow place of a pit without water, where they kept it sure, so that the place was unknown to all men. Now after many years, when it pleased God, Neemias being sent from the king of Persia, did send of the posterity of those priests that had hid it, to the fire, but as they told us they found no fire, but thick water. Then commanded he them to draw it up and to bring it, and when the sacrifices were laid on, Neemias commanded the priests to sprinkle the wood and the things laid thereupon with the water.

When this was done, and the time came that the sun shone, which afore was hid in the cloud, there was a great fire kindled, so that every man marvelled. * *

Verse 31. Now when the sacrifice was consumed, Neemias commanded the water that was left to be poured on the great stones. When this was done there was kindled a flame, but it was consumed by the light that shined from the altar.

So when this matter was known it was told the king of Persia, that in the place where the priests that were led away had hid the fire, there appeared water, and that Neemias had purified the sacrifices therewith. Then the king, enclosing the place, made it holy after he had tried the matter. And the king took many gifts, and bestowed thereof on those whom he would gratify. And Neemias called this thing Napthar, which is as much as to say "a cleansing," but many men call it Nephi.

In all succeeding ages the oil has been known, and to a limited extent it has been utilized. Herodotus mentions the Island of Zante as producing considerable quantities of the oil. Pliny and Dioscorides say that it was obtained at Agrigentum in Sicily. In later years Genoa and Amiens have been lighted by it. Probably there is no country in which coal is to be found, where the oil may not also exist, and in some few instances the deposits of oil may entirely replace the coal measures. It is now known to exude from the earth, or to exist in wells, some flowing in very large quantities, others requiring pumping, over the whole continent of North America, in Persia at Bakoum, in Pegu at Rangoon, in Russia, and even in the Island of Trinidad in the West Indies. In our own country at Matlock in Derbyshire, more recently in Yorkshire, and in France at Montrelais, smaller sources exist which

have been worked. But it was reserved for the present age, by means of that chemical science, which has been gradually built up by many truly eminent laborers in this and other countries, to make generally available these stored-up products of extinct vegetable and perhaps animal life. I am aware that the origin of earth or mineral oil has been the subject of much discussion, and as parrafin, when first discovered, was supposed by some to be the fat of extinct gnats, so petroleum has been by others imagined to be a product of deceased corallines.

But I think that we have strong grounds for asserting that mineral oil and coal have a common origin, the oil having been the result of heat combined with pressure acting on accumulations of vegetable matter, the coal having been formed wherever, without heat, great pressure was brought into action on the same substance.

In support of these views, I will adduce the well-known fact, that impressions so delicate and perfect, as to mock the best efforts of art, of vegetable structures so fragile, as to wither under the slightest increase of temperature, are constantly found in the coal measures. I speak of the impressions of the fern tribe in which the coal of Somersetshire is peculiarly rich. These, I submit, justify the inference, that when coal was produced no heat was present. But when we find that by the operation of a low red heat, oil can be produced, and is now largely supplied from this very coal, we are also, it would seem, justified in inferring that heat was applied by nature, when her supplies of mineral oil were stored up, and a clear understanding of this part of the subject, will materially aid us in coming to a correct conclusion both as to the quantity of oil which we may expect to obtain, and the price at which it will eventually be offered.

He who should set fire to a forest of noble trees in Europe would, at least in modern days, be considered as a wasteful spoliator, but till lately no one had a word of reprobation for those who got rid of a mountain of slack or small coal, (such as may be seen to the amount of millions of tons at the mouths of our coal pits), by setting it alight to burn unceasingly for months. Yet this was but the forest in another form—quite as available for human use, had we known how.

The patent of Mr. Young having expired within the last few months, a thriving industry has sprung into existence, and is being rapidly developed, having for its object the conversion of these waste heaps and of many of those imperfectly formed coals, which have had but little value hitherto, into parrafin oil. The distinction which is made at present, and which is often a distinction without any very material difference, is this, petroleum is obtained from natural sources direct in the first instance, parrafin oil is obtained by distillation of coal or coal shale at a low red heat. Parrafin oil does contain aniline colors, petroleum does not; but the degree of danger in both is in proportion to the quantity of light spirit left in the oil, and it is extremely doubtful whether for every purpose connected with the development of heat, this volatile portion had not better be extracted. If this be entirely done, the danger of explosion of course disappears.

The method of doing this possesses considerable interest. The oil in the crude state as it comes from the earth, and the first product of the

coal distillation, partake of the same dark colour and thick consistence, though this latter quality is less evident in the oil as obtained by artificial means. This also has a trace of the rich colour which indicates the presence of aniline dyes, and which, as has been said, are either entirely absent or only present in infinitesimal quantity, in what I shall call the naturally distilled oils, as far as yet known.

The refining, or more properly the separating process, next commences, and this is conducted by means of stills or retorts carefully heated, and by slow degrees brought to the needful intensity of temperature. An extremely light spirit, called variously mineral naphtha, mineral turpentine, or Eupion, makes its appearance, and runs for a time proportionate to the richness in this peculiar product of the oil operated upon. Suddenly the thermometer attached to the still, indicates a considerable increase of temperature, and this is an evidence to the operator that no more spirit of that specific gravity need be expected; so he shuts the tap and changes the vessel. The product of distillation is again permitted to flow, and now we have a light oil, specific gravity ·850, which may be burnt in lamps properly constructed.

Successive changes in temperature mark the coming over of different oils of varying specific gravities.

I have now given a slight sketch of the origin and method of obtaining these oils, and it remains that I dwell more fully on the main object of my paper, namely, the use of them as fuel for steam ships.

In considering the question of fuel for steam ships, the first requirement is an exact knowledge of the evaporative value of the substance proposed, that is, how many pounds of water can be evaporated by one pound of the proposed substitute for coal.

The second requirement is a comparative price at which it can be done.

If only one of these comparisons can be favourably made, then what are the countervailing advantages which should induce us to prefer the new to the old fuel?

With reference to the first requirement, it is impossible to ignore the fact, now for the first time being generally acknowledged by engineers, that the existing tubular boilers are, if not the worst, at least very far from being the best mode of economizing fuel in producing steam. Some models which are here will explain this fact and its cause.

Mr. Wye Williams, an able authority on these matters, has lately published the results of some experiments, which have been several times repeated by various engineers, and which went to show conclusively, that the first inch of the tubes in a locomotive boiler evaporated as much as the next ten inches, and twice as much as the succeeding lengths of twelve inches, whilst the waste heat in the chimney formed a very large proportion of the whole theoretic heating value of the coals. To obtain, therefore, the real evaporative value of any substance is a much more difficult thing to do practically, than would at first sight appear, and we must, for the present, be content with the nearest approach to perfection in this respect, which existing types of boiler permit. Mr. Richardson, who is present, will, I believe,

go more into this part of the subject, as he is now and has for some time been making experiments in that direction. I may briefly state, as a general result, that the impression now prevails that 50 gallons of crude oil are equal to one ton of coals. These results, be it recollected, were obtained with boilers which probably suited the oil even less than the coals which they were built to burn.

But even this is very encouraging. Assuming the specific gravity of the crude oil to be equal to that of water, we have a weight of 500 lbs. against one ton, or 2240 lbs., or $4\frac{1}{2}$ times less weight to be carried. There is to be added to this, as against the coal, all dust and ashes which must be carried, and cannot be burnt—a great proportion of the waste incurred in transhipment, and from various other causes which are always in operation at sea in practice, though they escape notice in the laboratory analysis.

I am aware that the very notion of burning such an article as petroleum for steam fuel has been ridiculed by several talented men of chemical skill, their arguments against it being entirely based on calculations of cost, but I venture to think that they have failed to appreciate the fact, that there may be considerations which would outweigh almost any expenditure which is probable for such a purpose, and that the price of an article on its entry into commercial consideration, is by no means to be relied upon as its ultimate cost.

We will now proceed to consider some of the advantages to our Navy and to certain enterprises of commerce which may be, and probably will be, derived from its use. It may be open to doubt how far the measure of 50 gallons of oil to one ton of coal is reliable, but it will be sufficient if we assume that this proportion is the true one, and suppose at the outset, that the comparison may be less favourable for the oil, but will not probably be more so. A steam ship is now generally able to carry from 9 to 13 days' fuel in the shape of coals, which may propel her at a rate of 12 or 13 knots per hour. This is probably a high average; but however this may be, it has never been sufficient to enable us to accomplish the voyage to Australia without coaling, unless with ships of a magnitude which renders the speculation an unprofitable one. Neither could our men-of-war maintain their position for any length of time off a blockaded port, except by having duplicate vessels and an expensive system of reliefs.

But if mineral oil be to coal in the proportion which has been asserted, $4\frac{1}{2}$ to 1, it is clear that not 9 to 13 but 40 to 50 days' fuel may be carried with no greater weight. This is indeed an advantage which may well outweigh in many cases the greater cost, supposing it to be unavoidable. For purposes of naval warfare, there is another consideration which day by day forces itself still more upon our notice. This is the unsinkability, so to call it, of our ships of war. It is no slight advantage of a fluid form of fuel, that it is capable of being carried in compartments or tanks, which again serve, by dividing the large space now necessary for coal bunkers, to help materially in preserving or augmenting the extent to which that cellular form of structure can be carried, which is the surest and best precaution against the destructive effects of shot or rocks. I believe that pretroleum oil will be

found to be highly preservative of iron, whether from internal corrosion galvanically caused, or from the external fouling, which is so serious a defect in our iron ships.

In the case of steam launches with twin screws, which all who have closely watched the progress of that admirable application of power, hope to see adopted more generally, as its merits are becoming widely known or acknowledged; in these launches, or comparatively small vessels, as gunboats, &c., the value of a fuel which occupies a less space than coal, will be still more strongly felt. The labours of bringing off stores, provisions &c., will be lightened and expedited in a manner not now easily attainable from the very small capacity for fuel, which even the largest boats of a man-of-war possess, and this will go far to repay the additional cost of the fuel; for I have often seen ships delayed when wanted for urgent service, by the impracticability of getting off some necessary stores in the teeth of a gale, too strong for oars to make way against, in propelling a heavily laden boat. I do not say this cannot be avoided by the use of coal for fuel, but only, that to avoid it becomes more easily practicable and to a greater extent, when a fluid fuel taking less room is substituted for the solid. What has delayed ships, may delay squadrons or fleets (of course I am speaking of a foreign port or anchorage, where ordinary tugs are not available), and thus it becomes very difficult to calculate what may or may not, be the gain to be put in the scales against the first cost of mineral oil as fuel.

It is certain that considerable economy of labour will be effected, for it will not require many stokers to manage a fire which requires no poking and makes no ashes. The abolition of that nuisance of getting up ashes every half-hour, which is no light one to those whose duty it is to walk the deck or work on it, with the said ashes blowing into their eyes, will, I am sure, be hailed by all my brother seamen with satisfaction, while the first lieutenants will be delighted to think that there will be no more antagonism between coal dust and clean decks, or fresh paint and blackened crews. What danger of explosion there may really be from the use of crude oil, I have shown to be easily removable, probably even profitably, for the light spirit is valuable as a substitute for turpentine in oil painting, and for many other purposes. But it is an error to imagine that even the crude oil would easily take fire from a red hot shot or a similarly heated body. The result would be the liberation of a great quantity of disagreeably smelling white smoke, but it is the vapour from the oil where it contains light spirit, which is likely to cause explosion when approached by flame. Among heat-producing substances, tallow occupies the foremost place, and the nearer we bring the earth oil to a similar condition by fractional distillation, the better will probably be the results we shall obtain, both in evaporative value, and in elimination of dangerous or useless elements. Among the latter, there is to be mentioned a carbonaceous residuum which attaches itself to the sides, &c., of the apparatus in which the oil is burnt, and which is certainly objectionable. To get rid of this, either distillation must be resorted to in the first instance, or provision must be made for its being burnt as a part of the fuel under

the boiler, or for other purposes. I should prefer carrying out as much as possible the principle of embarking nothing under the name of steam fuel, which is not available directly under the boiler, and in the highest degree, and just as it is better to sift coals, it would be better to distil petroleum. For it is not alone that there is a substance which does not give, or at least has not, under our present boilers, given out any heat to the water, but by incrusting the iron heating surface, it has impeded the full action of the really good fuel; therefore, such deposit is by all means to be prevented. We have here some interesting models to which the meeting will perhaps allow me shortly to refer, as they illustrate a new principle of boiler,* in which the thorough and unopposed interchange of the currents of heated and cooler water are provided for. Unless this be done, the full evaporative value of no kind of fuel will be obtained, and I show these models, by the kind permission of Mr. Field, in order that we may see this action in perfection, and understand how necessary it is that improved forms of boilers should coincide with improved fuel, and that in any experiments which may be made, fair play should be given to the new substance. If we are only now discovering the imperfection of the received form of boiler for heating water by coal, is it likely that we shall at once arrive at the best form for heating it by means of oil; neither can any great value be attached to negative results, were they obtained while using, for testing the evaporative value of oil, the old form of boiler, which as we have seen, is by no means excellent, even for the purpose for which it was built.

As Mr. Richardson will show, the oil, even under this unfavourable condition, has proved its value in his experiments to be nearly what I have claimed for it, 4 or 4½ to 1. With regard to the supply of mineral oil, I believe it to be for all practical purposes, inexhaustible, or at least not less so than coal itself. New sources of supply of the naturally distilled oil, are being constantly discovered, and in America, as well as in this country, there are a large number of companies for the developement of the traffic. Immense fortunes are being frequently made in the trade, and the query "How is oil"? is outstripping "How is cotton?" It is reported of a 'cute Yankee, that, finding himself in one of the capitals of Europe, in the company of a number of scientific men, he heard them discussing the discovery of a new planet, said he, "I don't vally a star more or less, can ye tell us the price of cotton?" But now oil, or as it is there pronounced "ile," has taken the place which the produce of the Southern States once held, and probably King Cotton is for ever dethroned. There are persons who will be jealous of any change which would take from England the monopoly of the best steam fuel, which she has hitherto had; but such views are too narrow to deserve serious consideration, for if the new form of fuel be the best, it is clear that other nations adopting it would obtain still more important advantages over us, by our refusing to use it, on whatever grounds.

The advantages of employing the oil, I have shown to be great, great enough, I almost think, to justify its employment at present

* See woodcut at page 70.—Ed.

prices. These prices, I have also shown, may probably be reduced, but there can be no question that the whole matter deserves the most careful attention, and the most elaborate experiments. It may be interesting to state that the exports from America were, in 1862 10,523,751 gallons, in 1863 27,195,189 gallons, and in 1864 31,121,800 gallons.

The price is at present, in this country, £18 per ton for crude oil, and £23 for refined, fit for burning in lamps, such as are now cheering alike the peasant and the peer with their brilliant, yet easily subdued and managed light, at a cost such as never was previously thought possible. Thus it may be employed as an illumination in the same ship in which a different quality is burnt as fuel; and here again the saving will be enormous, as compared with ordinary oil or candles.

I show the two most elegant and efficient lamps for house purposes, with which I am acquainted. These I have seen tested practically during more that two years, and I consider them easily managed, cheap, and perfectly safe, whether burning petroleum or paraffin oil, if only the precaution be taken to buy the oil where the specific gravity will not be fraudulently lowered below the proper point, or else to test it before using.

To give time for Mr. Richardson to follow, I have made this paper as short as possible, and now, after thanking you for your patient attention, I will conclude by reading an extract from a letter I have only lately received from an American friend (an engineer of considerable eminence, who was lately in this country), on the subject of petroleum as steam fuel. Of course this is a statement which must be taken "cum grano salis," but however much we may allow for the enthusiasm of a patentee, it will remain a most remarkable illustration of the necessity of distrusting theory when opposed to practice.

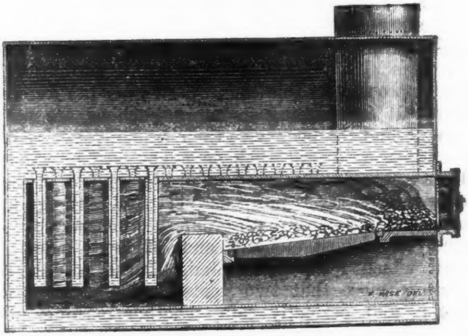
He says, "I have had an interview with the patentee of the process of burning oil under steam ships' boilers, they, *i.e.*, himself and a committee of engineers appointed by the Navy Department, have been trying experiments for the last eight months, the Government paying half the expense, and they, the patentees the other half. The manuscript report is now in the hands of the Government printers, and will not be out before February, he says I shall have one of the first copies."

He says "the saving is more than nine-tenths in bulk, and three-quarters in expenses, in running a steam ship from here to Liverpool or China."

I think it probable that, in order to obtain any thing approaching to this, which I cannot but say would be an extraordinary result, the oil must have been reduced nearly to the form of grease, which, as I have before said, would thoroughly carry out the principle of having as fuel, at whatever first cost, the substance which gave the greatest effect with the least bulk. I think that the present price of such grease would not be materially greater if derived from coal oil, than that which I have named as the present value of the imported, *i.e.*, £18 to £20 per ton.*

* The oil is now produced in this country at 75*s.* per ton (25th April, 1865.)—J. H. S.

THE "FIELD BOILER" (FOR STEAM SHIPS).



The above woodcut represents a longitudinal section of a marine boiler, manufactured with double tubes on Field's patent circulating principle, the leading feature of which consists in the use of a deflector top to the inner tubes, and the consequent non-interference of the upward and downward circulating currents with each other.

PETROLEUM AS STEAM FUEL.

By C. J. RICHARDSON, Esq., F.R.I.B.A.

PETROLEUM has hitherto evaded all attempts to be made use of as a fuel for the steam-engine. The modes adopted were either of too complicated a form or of too unmanageable a nature to be of any use.

The plan for using it, which I shall have the honour of describing to you this evening, is, I am told, chiefly remarkable for its simplicity and easily working character.

There are many erroneous opinions prevailing respecting the properties of petroleum. The general belief is, it is liable to explode spontaneously, or that it explodes, like gunpowder, upon contact with a lighted match, candle, or simple spark. This shows the utter ignorance that exists as to the true nature of the oil. Some of the common sorts do vapourise at low temperatures, and ignite upon the application of flame. The best samples may have a lighted match dipped into them repeatedly and yet do not inflame until the temperature is raised to 80° or 90° F.; they then only begin to evolve inflammable vapour. The heavy oils of Rangoon, Egypt, West Indies, and the English coal oil only vapourise at a very high temperature, having little of the

inflammable spirit. In its explosive quality the vapour exactly resembles common gas; it is well known that when gas is allowed to escape in any confined space, and mixes with the atmospheric air, it will, on the application of flame, explode.

With petroleum vapour, it has been stated that a single spark is capable of igniting it; but it is not so, it is not inflamed even by a piece of iron heated nearly to whiteness. The vapour is so volatile, that when in a place well ventilated, it will pass by flame without igniting. It exactly resembles the white jets of gas we see issuing out of coal in our common domestic stoves: if flame touches them when of a certain temperature, they ignite, but if they are not sufficiently warm, they go up the chimney, often by the side of flame without igniting.

When petroleum is kept in iron cases, no vapour can possibly escape.

In burning, there appears always to be a thin film or stratum of air or vapour between the flame and the oil. If the latter, while vapourising and burning, floats over a wooded floor, when exhausted, the flame flickers and instantly expires, and the wood is not even singed or discoloured. Of course, if linen thread or a wood splinter project into the flame, they take fire.

When the vapour takes flame, the temperature of the body of the oil increases until it is in a boiling state; the vapour is given off more rapidly, and the flame is intense until the whole is consumed. It is very important to understand the working of this, as it is a very valuable property when the oil is used as steam fuel.

There are five or six different products obtained from the crude petroleum by the distiller, all of them of greater or less value. It is sufficient for our purpose to divide these into three products only.

The first of these is the petroleum spirit, a clear highly volatile liquid, used, among other purposes, as a substitute for turpentine. This spirit, when extracted from the crude oil, vapourises at common temperatures, and is highly inflammable; but when it forms part of the crude petroleum, it vapourises only at 80° or 90° F., being, as it appears to me, neutralized by the two other portions of the oil.

The next of the products is the burning oil, of which there are several varieties. The best samples, when extracted from the crude oil, do not give off vapour under 112° or 130° F. When it forms part of the crude oil it does not vapourise near so readily.

The last product is the heavy petroleum, as thick as tar. It does not vapourise until it reaches a very high temperature. It appears to me that it must be made to boil before it will do so. It is this product that neutralizes the two former.

This heavy petroleum is the most valuable portion of the oil when used as steam fuel.

Now, when the crude oil is raised to a temperature of 80° or 90° F., it is the petroleum spirit that rises and becomes inflamed. In burning, it raises the temperature so high that the burning oil vapourises in its turn, and this, having raised the temperature of the remainder to boiling point, the residue, the heavy petroleum, vapourises and burns fiercely.

A mode, or *an attempt* to make use of the oil as steam fuel, by Messrs. Shaw and Linton, was tried and examined by the American and French Governments.* It appeared to have been based upon the principle of burning, the three products in separate chambers.

Fig. 1, Plate XI, is a representation of Messrs. Shaw and Linton's petroleum steam boiler.

A, Feed-vat containing crude petroleum.
B, Pipe conducting petroleum to
C, the hot chamber, where the inflammable spirit is converted into vapour.
D, Hot plate.
E, Tube by which the petroleum falls into the hot box
F, where the burning oil vapourises. It has an opening at bottom, to allow the heavy petroleum to fall among the embers of a wood fire, being caught on ledges of receiver, G.
H H, Boiler flues.
I, Chimney tube.
J, Opening for vapour to escape into combustion chamber, K.
L, Wood fire.
M, Fire door.
N O, Air pipes.
P, Boiler.

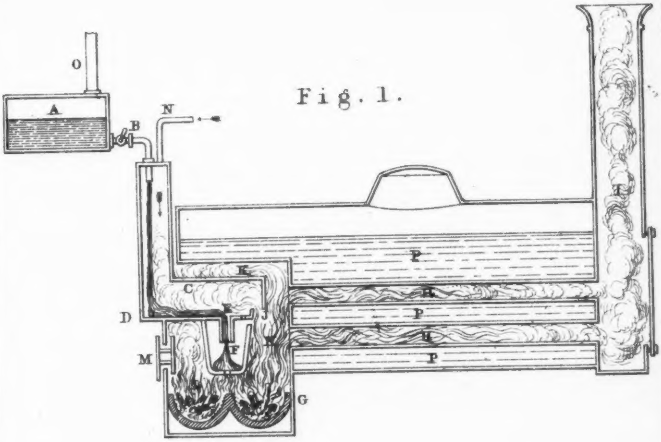
To commence operations, a wood fire was lighted in the receiver L. When the hot plate D and the box K were sufficiently heated, the petroleum was allowed to enter. It appears to me that by this method the oil was not sufficiently under command to render its burning successful.

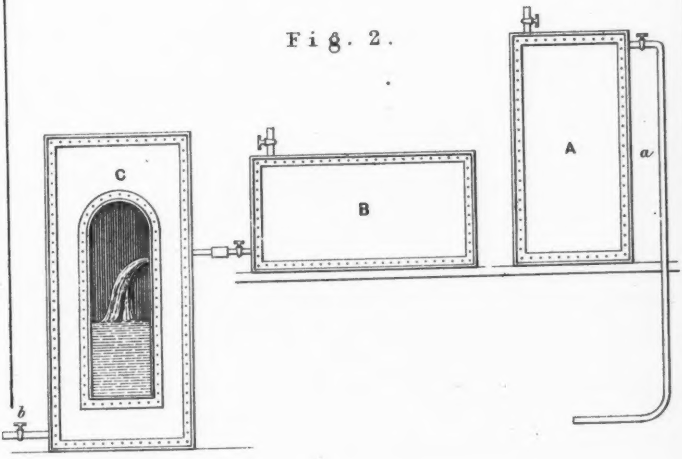
The crude oil owes its character for vapourising at a low temperature solely to the presence of the petroleum spirit. Its sole use in the oil, according to my mode of using it as steam fuel, is that it causes the oil to take fire more readily. My grate can be started in less than a minute. If this petroleum spirit was extracted from the oil, the fire in the grate would take longer to light, probably eight or ten minutes, but the oil would be entirely deprived of the character of spontaneous combustion which timid people and alarmists now apply to it. I have no fear of the spirit, and would rather it was not extracted. When the oil is kept in iron or metallic cases no vapour can possibly escape; the oil can be made to run into the grates as easily as gas into a gaselier, without any exposure to the atmosphere.†

I have here half a pint of crude oil. In these three bottles are the

* Mr. Henry Simpson's English Oil Trade Review gave a full description of it.—C. J. R.

† Already there is evidence that people are becoming convinced of the foolishness of regarding petroleum as being so extremely dangerous as it has been represented. Insurance Companies that have been charging from 7*l*. 7*s*. to 10*l*. 10*s*., on petrol afloat from America have now reduced their charge 2*l*. 10*s*. (1863). In Belgium the Minister of the Interior has declared that petroleum is not to be considered as one of the articles of inflammable merchandize which must be treated by special regulations, as essentially dangerous. It is shewn by Captain Shaw, Superintendent of the London Fire Brigade, that 124 fires were caused by gas during the year 1862, whilst only two were caused by naphtha or mineral oils.—Dr. Tate.—C. J. R.





J.R. Jobbins

relative quantities of petroleum spirit, burning oil, and heavy petroleum the half-pint contains. These have been divided for me by Mr. Wright, the chemist, of Kensington.

The oil is not explosive; when contained in iron cisterns or metallic cases carefully closed, it might vapourise without danger. The manufacturers of these cases allow space, or have a contrivance for permitting extra vapour in a warm climate.*

This vapour could be utilized. I have shown here an arrangement for that purpose. The upright tank is in its first position. It has two taps at top; to one a flexible india-rubber tube is fastened, which conducts the vapour to any fixed iron pipe, which opens into the furnace. When this tank is wanted for the furnace, it is laid on its side, the tap opened to let in air. This tap lets the oil flow into another tank, having a plate of glass in front, so that the engineer may see whenever a fresh tank is required.

Fig. 2, *Plate* XI.

A Iron tank containing petroleum; *a*, flexible tube allowing vapour to escape to furnace.

B Same tank, placed on its side, the petroleum running into tank C, which is provided with a glass front, to show height of petroleum.

b. Pipe conveying petroleum to grate.

Some manufactories have already adopted the plan of collecting the gas evolved during the process of refining petroleum, and using it for lighting purposes. Mr. Prentis, of Birkenhead, does so, and that gentleman states that he effects by it a considerable saving. Petroleum produces a gas absolutely free from impurities, and one foot of oil gas gives the light of three feet of ordinary coal gas.

A time may arrive when every householder, by keeping a tank of petroleum in the upper part of his dwelling, could have flame laid on to every stove in his house, as well as gas to his gaseliers, rendering him alike independent of the coal merchant and the gas company. At present petroleum certainly has a bad name. During the time I was carrying on my first experiment at Chelsea, one of the adjoining householders, ascertaining what was going on, and seeing that the chimney funnel leant against his premises, came and forbade me to proceed, unless I fully undertook to rebuild his house in case it should be knocked over by the explosion of my barrel of petroleum. Of course I complied with his request. An article in the "Times" of the 6th of April, on the importance of discovering a mode of burning petroleum as steam fuel, first led me to take up the study. I have been repeatedly asked why, not being an engineer, or professing to know anything of the steam-engine, but being only an architect, I should venture upon such a study. My reply has been, I have had considerable experience in the warming and ventilation of buildings, and in the construction of hot water furnaces for such purposes. I meddle with the furnace, not the steam-engine.

* 87,196 barrels refined and crude imported in 1864 without accident.—C. J. R.

My first endeavour was to make an artificial coal by mixing the oil with the most worthless porous material I could find. Slate dust was selected, but it did not answer. In taking a piece of lime and soaking it in petroleum, it sucked up a quantity about equal to its own cubical contents, and permitted the petroleum to burn so slowly that the whole of it was utilized. Other porous materials equally allowed it, the harder kinds burning slowly, the softer kinds quickly. Petroleum, I saw, required a porous stone wick, not a cotton one.

Probably the best porous material to use is the petroleum coke, the product remaining in the still in the process of refining. It is at present nearly worthless, used to mend roads, or as a poor fuel.

In my small models, formed either of tin or zinc, the oil was burned with perfect impunity. The thick Rangoon, or the heavy petroleum, was well mixed with a little spirit to make it more fluid. The vapour, when it escaped, appeared harmless. It often went up the chimney by the side of the flame without catching fire, and lit only when a lighted taper was held to it; but when the model had been in action half an hour, the vapour highly heated, inflamed of itself, and was then difficult to extinguish. This vapour tube I now place in such a position that the gaseous unconsumed matter from the grate passes over it, and there is little or no smoke.

Plate XII is a representation of my first petroleum grate.

Fig. 3. Plan of grate.
Fig. 4. Long section of ditto through centre.
Fig. 5. Cross section, looking towards front.
Fig. 6. Continuation of long section.
Fig. 7. Section of bar to a larger size.

a. Porous material.
b. Oil trough.
c. Feed-water.
d. Entrance for ditto.
e. Exit for ditto.
f. Vapour chamber.
g. Vapour tube.
h. Tube for petroleum and oil pipe.
i. Tap to admit petroleum into grate.
j. Tap to draw off petroleum, Tap *i* being closed.
k. Glass tube showing height of oil.

The porous material holds the oil, and prevents it burning too quickly. The vapour tube, when in full flame, burns the gaseous smoke. The oil, when inflamed, tends to become intensely hot. It is kept to its proper temperature for vapourizing by the water in which the oil trough is placed. This takes away the extra heat, and is made to boil and steam. The oil is perfectly under command.

The grate was placed under a boiler at Chelsea, a cylindrical boiler, which required a good consumption of coal—about 12 cwt. a-day. It was of 6-horse power, and with the water cold, required wood and about 3 cwt. of coal to start it. I had to reinstate nearly the whole of the brickwork, which had been broken away. The brickwork was

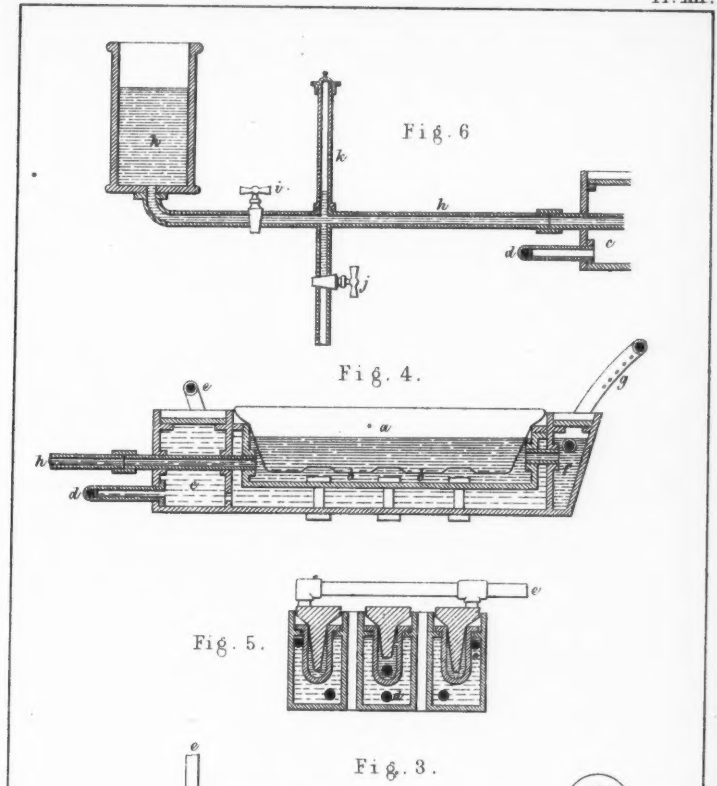
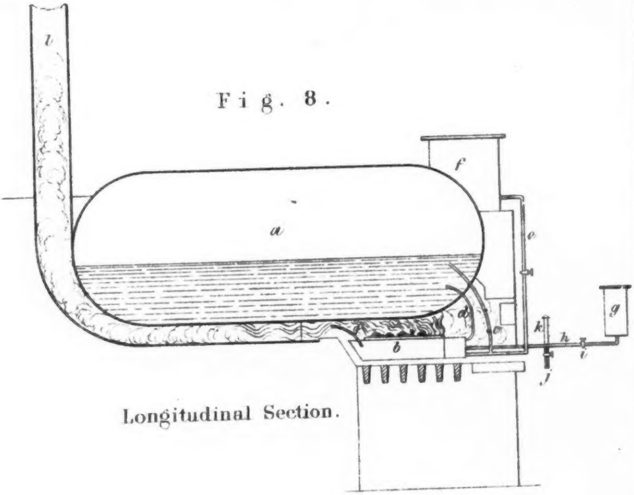


Fig. 6
h
k
i
h
j
d
c
Fig. 4.
e
a
g
h
d
c
b
f
Fig. 5.
e
d
Fig. 3.
e
a
h
f
g
a
d
Fig. 7.
a
e
c
d
12 9 6 3 0
1 FOOT

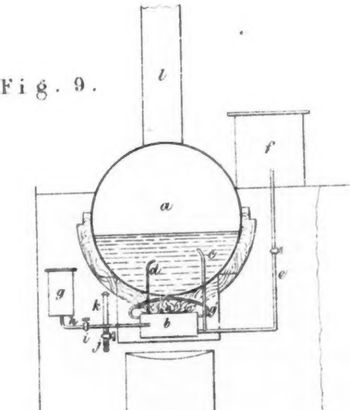
J R Jobbins

Fig. 8.



Longitudinal Section.

Fig. 9.



Cross Section.

Scale ¼ In: to a Foot.

therefore wet. There was too much air space, and the draught was too direct.

Fig. 8.—Plate XIII represents a longitudinal section of the boiler; and Fig. 9 a cross section of the same.

a. The boiler.
b. Petroleum grate.
c, d. Flow and return pipes, causing a circulation of the water through boiler and grate. (These were added on the second experiment.)
e. Feed-pipe.
f. Feed-water cistern.
g. Gallon measure, containing crude petroleum, which was admitted into grate by the tap *i*.
g'. The circular vapour tube, having about 20 small holes. Fig. 9.
h. Tube for petroleum and oil pipe.
k. Glass tube, showing height of oil in grate. Two lines are shown crossing it. When the oil stood at the upper line, the grate was fully served, and the fire burnt fiercely.
j. Pipe for emptying oil out of grate.
l. Chimney shaft, 10 inches diameter; height 15 feet.

Common salt was used as a packing, with not quite two gallons of oil, and in about 2½ hours, we only raised the temperature of the water 30°. The temperature of the feed-water, which passed through the grate and ran to waste, was from 168° to 247°, keeping the flame of the grate very low. There was too much feed-water, and the plan of running it through the grate was bad. A few days after, the water from the boiler was made to pass through the grate by the flow and return pipes *c* and *d*. Then the steam was raised in about three hours with an expenditure of 2½ gallons of crude petroleum—and this with the vapour escaping—the vapour tube did not act, the vapour chamber being placed too low in the grate. When the stoker lighted a few shavings beneath it, the vapour burst out in brilliant jets of flame, and the smoke from the funnel became almost colourless. The vapour chamber is now placed above and not below the grate.

The grate was, by the kindness of the Admiralty, moved to Woolwich. It was there placed under the boiler of an engine of 14-horse power. It succeeded in getting up the steam in an hour and a half, and for another hour the steam blew off fully, the valve fixed at 10 lb. pressure; a little more than four gallons of oil was used. The engine could have been started, but the grate, from its small size, would not have made sufficient steam to have lasted above ten or more minutes. There was a waste of oil in this experiment, a large mass of cold air being admitted behind the grate, causing a great deal of smoke, and consequently waste of oil. The grate was not sufficiently strong to bear the pressure, not being originally constructed for the boiler water to pass through it. It really acted as a steam trap; it cracked and opened at the joints, the steam entering and turning the oil out.

Plate XIV, Figs. 10, 11, and 12, show the plan and sections of

boiler, with position of grate. The letters to the parts are the same as those in Fig. 9, *n*, Fig. 11, portion of the coal grate.

The engineers, on first seeing the grate, did not believe it was possible for such a small model, which seemed to them a mere toy, to raise the steam in such a boiler.

The coal grate was 9 ft. super; if this had been reduced to 2 ft. super, the size of my grate, I much question if it could have raised steam at all; it certainly would not have done so unless in eight or ten hours.

I endeavoured to mend or tighten the joints by additional screws, and to rust up the cracks, thinking that, although it might not be able to stand pressure, it might serve to evaporate water. On being again placed under the boiler, when evaporation commenced, every supply of oil opened the joints, till the grate became half filled with water. It was evident that the grate should be of wrought iron, and form part of the boiler itself.

The boilers at Chelsea and at Woolwich were coal boilers, not well adapted to petroleum. A suggestion for a petroleum boiler is shown in Plate XIV :—

Fig. 13. Plan.
Fig. 14. Long section.
Fig. 15. Cross ditto.
Fig. 16. Portion of grate to a larger scale, showing air pipes $2\frac{1}{2}$ inches apart, the whole length between bars.

The plan shows an oil pipe to each bar, to permit either to remain unlighted.

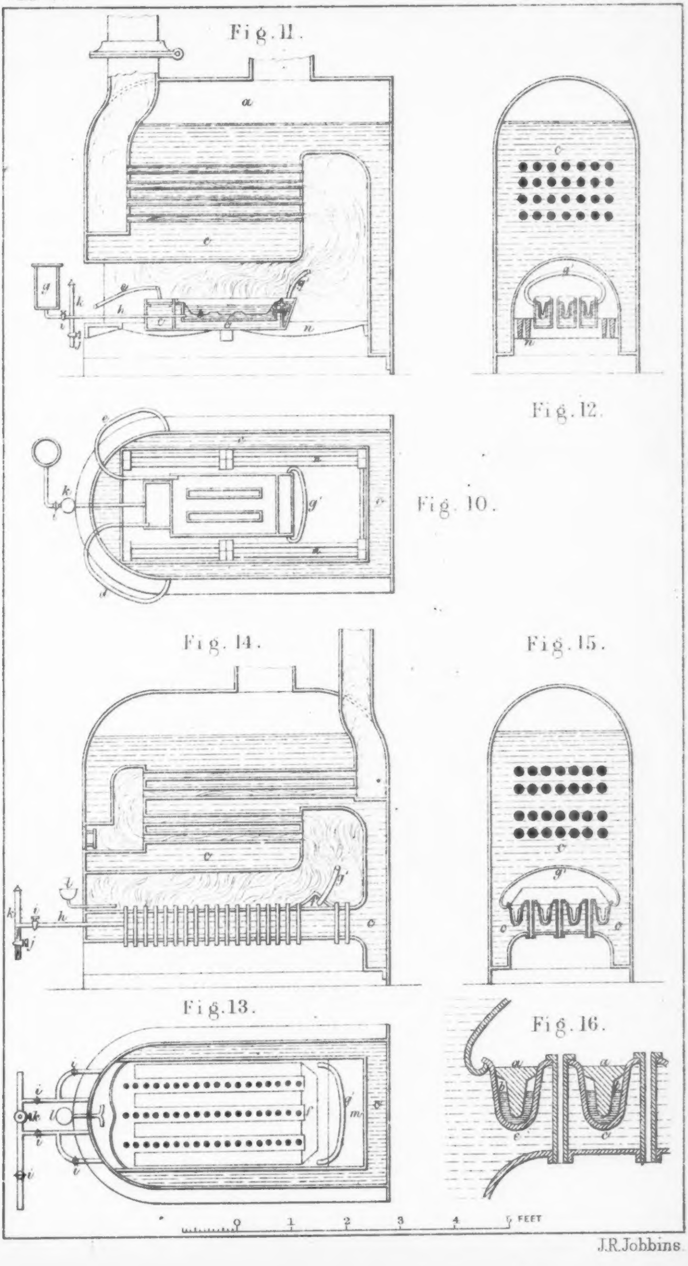
l. A cup to allow petroleum to be run on the surface of grate to the space *m*, giving extra power when required.

Several experiments were made with the grate to each boiler, and they all proved, that with the supply of oil and the supply of air nicely proportioned to each other, the full utilization of the oil would be obtained, with little or no smoke; that the oil permitted that great desideratum, mechanical management; and that it would be as easy to work twenty furnaces as one, the oil being laid on just like gas to any number of gaseliers.

My assistants, an engineer and stoker, men of considerable experience, said the experiments proved that three gallons of the oil might safely be put against 2 cwt. of coal as their equivalent, but I will say four gallons. Forty gallons are therefore equal to one ton of coal, and one ton of the oil itself fully equal, as steam-producing power, to five tons of coal.

In stowage, petroleum occupies less space than coal. Without, however, taking this into consideration, if one ton of petroleum is equal to five tons of coal, the whole of the 10,000 tons of coal of the "Great Eastern" could have been represented by 2,000 tons of oil; the 1,400 tons of the "Persia" and the "Adriatic" by 280 tons. In every 100 tons of coal, a saving could be effected of 80 tons for freight space, and this of the value of £7 per ton; and the ships relieved of two-thirds the number of stokers and coal passers. The amount of profit of petroleum over coal can, therefore, be easily estimated.

The question naturally suggests itself, why is it that petroleum as



J.R.Jobbins.

steam fuel is so much more powerful than coal, one ton producing as much steam-power as five tons of coal? Some eminent chemists both in England and America have stepped forward, apparently to shut up the question, not to allow of its being discussed at all; it is too improbable, they state, that the relative amount of carbon and hydrogen in petroleum is, in round numbers, six parts of carbon to one of hydrogen. Whereas, in coal, the amount of hydrogen is less in proportion; that there is also a small amount of oxygen present, which diminishes the heat-producing power; the result is, that the heat-producing power of petroleum is greater than that of an equal weight of coal, it is in fact about half as much again; and they continue considering that as the price of petroleum is from £15 to £20 per ton, and that of coal 15*s.* a ton, it is a fallacy to suppose that petroleum can be substituted for coal as steam fuel.

The first learned chemist, John Rudolph Glaubier, who, about the year 1650, saw the now celebrated coal oil run from his still, appeared to have had no idea it had any burning power at all, he thus speaks of it:—

"But if you cast in stone-coles alone by themselves, and distill them, "there will come over not only a sharp spirit, but also a hot and blood-"red oyle, which doth powerfully dry and heal all running ulcers; "especially it will heal a scald-head better than any other medicine, "and it doth consume all moyst and spongious excrescencies in the "skin, wherever they be."

The objections brought forward are very easily answered. First, as regards expense, for if that can be settled, there may be a little dispute about other points.

An English skipper is not likely to be so simple as to select the best Pennsylvania crude oil at £18 to £20 per ton, when he can obtain English crude Flintshire oil, which is quite good enough for his purpose, at £9 or £10 per ton.

(Large districts in Wales and Scotland abound with the oil producing coal, which may be said to be as inexhaustible as the coal used for burning.)

The skipper might select the Wallachian or the Barbadoes petroleum, just as good, and nearly about the same price; he might, at all events, content himself with any of these until his ship arrived at an oil producing district, where it could be obtained, at first cost, 300 to 400 per cent. less than it could be obtained in this country; and as there is little doubt but that mineral oil exists in all parts of the world, being far more generally distributed than coal; whatever part his ship arrives at, in any quarter of the world, he has only to send his metallic cases to be filled, with oil properly prepared for him, just as he would send his casks for water.

At Rangoon we have enough oil to supply all India. We have it at Trinidad, Barbadoes, Canada, California, Egypt, Greece, Austria, Turkey, Persia, and other places.

Taking the average price of coal at 15*s.*, is both unfair and incorrect. Midway between England and Australia the price is £3 per ton; in the Indian and China Seas it is from £4 to £5 per ton.

The average price to calculate upon is not £17 against 15*s.*, but £10

against £2. But taking the first prices with freight at £7 per ton, the saving of four tons out of five, leaves £14 15*s.* per ton in favour of petroleum. If we take the latter prices, £10 and £2, and freight at £5 per ton, reduced from the superior facility offered. the gain in favour of petroleum would be £20 per ton. The contemplation of such a gain is startling; a ship requiring 500 tons of coal, using instead 100 tons of petroleum, would gain by the exchange £2,000, and this without calculating the advantage of being able to go from port to port without turning aside for fuel, and with fewer landsmen on board, for such I suppose are the stokers. With Government vessels, all coaling stations would become unnecessary.

It is not a question as to which fuel contains more or less carbon or hydrogen, but which can be so utilised as to produce the most steam.

Petroleum requires a moderate amount of air to enable it to burn; if too much air is supplied it produces waste and makes smoke. The grate is started instantly, and it burns as quietly as the flame of a lamp, it requires a small chimney, the smoke or vapour is so volatile it escapes out of any crevice left for it.

Coal requires a large amount of air, 150 cubic feet of air, at atmospheric pressure, is required as the absolute equivalent for each pound of coal. As in common practice this cannot be supplied, the quantity of fuel used and the heat generated is greatly in excess of what can be utilised. Active firing, when a great demand is made for steam, causes half the fuel, or more than half, to go off in the form of dense black smoke—it is not smoke, but really all the valuable hydrocarbon and gas contained in the coal.

By careful firing, and the use of the Argand furnace, the invention of Professor C. Wye Williams, the smoke can be prevented and the fuel more fully utilised; but there is a prolific cause of waste which is beyond the power of any Argand furnace or careful firing to cure. Coal can only be burnt by placing it in a strong draught or current of air; to obtain this it must have a tall chimney-shaft, the taller the better, as the stronger becomes the draught.

This current of air must be first formed, before the coal is put into the furnace; it is done by firing logs of wood, the furnace doors being left open; when coal is put in, the draught is so strong that a welding heat is often obtained from the fuel, the grate bars are often burnt or destroyed; the heated current of air passes through the tubes and flues of the boiler at the rate of several hundred cubic feet per minute. It is the office of the tubes and boiler flues to obtain from this current as much heat as possible for the creation of steam. When the current reaches the chimney-shaft it represents the escaping products of the coal into the atmosphere, and is never less than 600° F.

In a late work by Mr. C. W. Williams on "The Steam Generating Power of Marine and Locomotive Boilers," he details three experiments made with the Argand furnace as to the best form or arrangement of the tubes to obtain the greatest amount of heat from the coals. He starts by saying that the tubular system, that grand and chief reliance of all engineers for the last thirty years, is altogether a mistake; that

beyond the first twelve inches of the tubes they ought to be left out of all calculation as heat-producing surfaces, and should be regarded only as mere conduits for conveying the heated products of combustion to the chimney. He gives the temperature of the waste heat in the chimney to each of his three experiments—to the first, it was 1060°; to the second, when he divided the tubes into two lengths, it was 760°; and to the third, where he divided the tubes into three lengths, it was 635°; and this, be it particularly observed, with the consumption of the average quantity of 3½ cwt. of coal to each experiment. I should like to ask any person who maintains that coal can be fully utilised, what is the temperature of the waste heat in the chimney of a furnace where from twenty to thirty tons of coal are burnt per day. We all know that the current is so strong that it often carries up with it small coal and cinders; that the heated gases often take fire by a spark from the furnace, and burn at the top of the funnel with a fierceness almost equalling the flame from a blast furnace, and with a noise rather disagreeable to nervous people in its vicinity. This waste heat and flame is certainly not being utilised, it is not making steam, and the coal is therefore wasted. We shall never fully appreciate or learn our present wicked waste of coal until petroleum supersedes it both in our locomotives and our steam ships.

I am not engineer enough to determine whether Professor C. Wye Williams, in his attack on the tubular system is right or wrong, but this I do know, it would be far wiser to abandon a fuel that will not be thoroughly utilised and turn to one that fully permits it—a fuel that appears to have been expressly formed and offered to man by a beneficient and kind Providence as a means to enable him to carry out steam navigation to its utmost possible development.

[Captain Selwyn gave the following verbal explanation of a model referred to in his paper:—The outer of these two tubes terminates at the bottom, and contains water. The inner tube is open at the bottom, and the result is, that as soon as the outer tube is heated, a current of heated water ascends in it. This you may see by the ascending black particles of charcoal, and the equal distribution of the water is restored by its descending in the inner tube. This is the very clever invention of Mr. Field. The steam is raised in the boiler quickly, owing to the interchange of currents which takes place. You will observe that the small particles are constantly ascending in the inner, and ascending in the outside tube.]

The Chairman: If any gentlemen wish to ask any questions or to make any observations upon the interesting discussion we have heard already, now is the time, I think, for them to do so.

Mr. Paul: Your Grace, I beg to make a few observations with regard to the papers which have been read by Captain Selwyn and Mr. Richardson. I have watched with very great anxiety for some evidence which Captain Selwyn appeared to promise would be given, and which I certainly expected would have been brought forward by himself or by Mr. Richardson, of the very startling fact, or the very startling statement—I cannot say less than startling—that has been made, that petroleum is capable of producing an amount of heat in effect equal to four times its weight of coal. It appears to me that that is a thing that any one conversant with the source of the heating power of combustible materials, will agree with me in saying is inconsistent with all that is known with regard to heating materials, or fuel; and it requires very strong evidence indeed before one can accept any approximation to that statement. From one point of view it is very easy to determine what can be the efficacy of two different materials when burned—that is, from their composition.

It is well known that the material which gives the greatest heat of any that is known, is carbon in its purest state as gas charcoal—the lining of a gas retort. It gives a greater amount of heat than any other material that is known; and the heat that is produced by the burning of carbon, is also capable of being turned to useful effect to a greater extent than that from any other kind of fuel. Therefore, the heating power of any fuel is proportionate to the amount of carbon which it contains. Now, between petroleum and coal there is no very great difference with regard to the amount of carbon. The coal contains, perhaps, about 83 per cent., and petroleum rather more; but there is, besides that, a quantity of hydrogen which increases the heating power, and makes it about one and a half or twice that of coal. However, I will not weary the meeting by entering into a statement of the chemical arguments, upon which I would object to the statements which have been made with regard to petroleum being used instead of coal. There is only one observation which I wish to make, and which, I have no doubt, will be more easily appreciated by those who are conversant with the use of fuel in marine boilers. It is well known that there is a difference between the efficacy of different kinds of coal in marine boilers. The Welsh coal and the north country coal have very different heating effects when used in the ordinary way in the ordinary marine boiler. But their heating powers, theoretically considered, are not very different. However, when Newcastle coal, which is admirable for certain purposes, is used in a marine boiler, the same amount of effect cannot be produced by it, unless particular precautions are taken, and special arrangements made, in the burning of it; whereas the Welsh coal, without any special trouble, or without any special precautions, will give a far greater amount of steam, and burn with greater convenience. Now, the difference between the two materials, to which that different effect is due, is that Newcastle coal contains about 30 per cent. of volatilizable matter. We all know that Newcastle coal, in burning in an ordinary grate, gives an immense number of jets of brilliant flame; whereas Welsh coal, or what is called "stone coal," burns with a dull, dead glow, without much flame. Now, in a marine boiler, when these two coals are put on to the fire, the Welsh coal, not giving off any of this volatilizable material, which in its nature is very analogous to petroleum, burns in the furnace itself, and it is merely a heated gas that has been perfectly burned, that passes into the tubes of the boiler. Its office is merely to give up the heat it holds, and transfer it to the tubes of the boiler, and thence to communicate it to the water; while with the Newcastle coal, on the contrary, there is a quantity of this volatilizable material given off. It is not in a state capable of being easily burned. It will not burn even when mixed with air, unless it has a certain temperature; unless the temperature of the mixture of this gas with air is maintained at a certain degree, it will not burn. Now, when it goes into the tubes of the boiler, within the first few inches it is cooled down; the heat that it possesses is transferred to the water, and the gas is cooled down to such a temperature that it will no longer burn. It then deposits its carbon, and passes out from the tubes into the chimney, and there, coming into contact with a fresh supply of air, it will take fire, and very frequently burn. Now, that is the difference between the effects of using Newcastle coal, which is smoky, and contains a quantity of volatilizable matter, and Welsh coal, which contains none. Now, applying that comparison to petroleum, I should like to ask the gentlemen who have experimented on this subject, How do you propose to burn petroleum in the ordinary tubular boiler? because petroleum is entirely volatilizable, and, though it burns with great ease, it is very easily volatilized. When that vapour comes to be carried into the tubes of a marine boiler, I should imagine that, instead of realizing an effect proportionate to the heating effect that can be realized from coal, the amount of heating effect will be proportionately very much less, because of the greater amount of volatile material that it contains. Certainly, it has been stated that our tubular boilers are not the best means of burning even coal; but at present we have nothing but tubular boilers, and any fuel that is used, must be used in tubular boilers for a time. As it has been remarked, if petroleum is to come into use, a special boiler will be necessary; but I think that before the use of petroleum can be urged with any reason whatever, there must be very satisfactory evidence brought forth; and, in my own belief, no such evidence can be brought forward to show that it is capable of being used as an equivalent for coal.

Mr. Frank Wright, Chemist: Like the last speaker, I have been very much interested in both papers that have been read this evening, and, like him, I came to hear them with several scruples on my mind, which I did not expect to have removed. I have been rather more fortunate than he, for some of those scruples have certainly been removed, and some of the difficulties which now seem still to cling to him, have vanished from my mind. One of these difficulties, with reference to which, he calls for special proof, was that the combustion of petroleum should produce so much more heating effect than coal. I am accustomed to look upon a practical question of this sort purely from a practical point of view; and though I am quite aware that in a rough manner, and all other conditions being equal, we may pretty fairly estimate the heating quality of any given body from its composition, yet I think it is only right, before we come to any conclusion, that we should put the particular substance to the test of actual experiment. That is the kind of evidence which, I think, alone ought to satisfy us in a matter of this kind. That evidence Mr. Richardson's statement has to-night supplied. He tells us that at Woolwich, in a steam-boiler built for other purposes, and to consume other materials, working under every disadvantage which you could very well conceive, petroleum did actually produce an effect five times as great as could reasonably have been expected had coal been the combustible used. Of course, not having been present at the experiment, I am unable to ascertain how far all the data of this conclusion are to be relied upon; but so far as the facts appear before us to-night, there is at least strong *primâ facie* evidence that the gentleman who has read the last paper has not been too sanguine in favour of his petroleum. I should also say, that I think it is as well in judging a matter of this sort from theoretical points of view, we should bear in mind that the heating quality of any particular article, when burning under certain conditions, is a matter very much in dispute; and perhaps there are not two experimentalists who actually agree as to the amount of heat which can be got out of an article when burned under the same conditions. It should also be observed that not only is there this variety of opinion as to the amount of heat to be obtained from burning bodies, but the question which, as practical men, we have to consider is, not what is the amount of heat you can evolve by burning a thing, but what is the amount of heat which, when it is so burned, you can *utilize* for purposes of art. Now, Mr. Richardson has taught us to-night that, by a peculiarly constructed grate of very small area, requiring but a very small quantity of air (which in our ordinary furnaces carries off so much of the heat that is generated), he is able so to utilize the heat produced, as to exhibit effects surpassing all expectations founded on previous experience. The last speaker has pointed out to us very clearly how this difference in the manner in which an article is consumed, may produce a very great difference in the effect obtained. Thus, he has shown us that Newcastle coals, between which and ordinary Welsh coals there is not a very wide difference as to ultimate composition, nevertheless give a very different result in the amount of heating effect produced; and I look for an explanation of the utility of petroleum as ordinary fuel in marine boilers in the same direction. If it can be shown, as Mr. Richardson has pointed out to us, that conditions are available to us in burning petroleum which are not available in burning coal, then I think we have an opening presented to us through which we may fairly look for the benefits which he promised us. With respect to the difficulty which the last speaker has pointed out, and which he dwelt upon as the cause of the inferior heating quality of Newcastle coal when burned in the ordinary manner, namely, the volatility of a large proportion of the products of its combustion; so far as that difficulty applies to petroleum, it should be observed, I think—at least, this is the manner in which I understand it from Mr. Richardson's case as put before us to-night—that the article consumed is not petroleum, but petroleum vapour; for by the construction of his furnace the petroleum must be first converted into vapour, and then burned. It would seem that the objection would have very great force, provided the petroleum was burned direct, and the heat of that combustion was then allowed to convert the surrounding unburnt petroleum into vapour, for then much unburned petroleum might escape in the flame; but, as I understand the construction of the furnace, no vapour can escape except through the porous material, and that porous material constitutes the grate itself, where it meets with all the air needed to burn it. The objection,

therefore, which lies against Newcastle coal cannot possibly lie against petroleum burned in such a grate. No volatile fuel can pass off by the flue, unless it happens that the negligent stoker does not provide a proper supply of air to burn up all the vapour as it passes off from the porous material. That, however, is only a defect which careful stoking can provide for. I have dwelt upon this, because I had myself some difficulties of this sort, but which have been explained away by the author of the paper. I only regret that the explanation has not been universally satisfactory, and hope that these difficulties do not remain generally upon the minds of the audience. As Mr. Richardson has very properly pointed out to us, this is not purely a question of the value of one fuel as pitted against another, so far as its heating quality is concerned; for if it can be shown that by the combustion of one material instead of another you can get five, six, eight, or ten hundred tons more stowage room out of a vessel of two or three thousand tons, that is a most important element in the calculation, and one which cannot be ignored in considering the ultimate pecuniary advantages to be derived; and I must confess that though I do not see my way to all the great things which he promises, yet I do think that it is a subject which deserves the utmost freedom of discussion, and upon which most extensive experiments will be amply rewarded and justifiably entered upon.

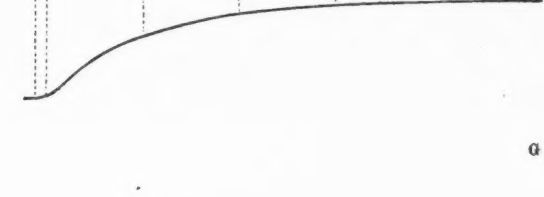
Mr. PAUL: I must state that I consider that a most desirable addition to the papers would have been a statement of the data upon which the evaporative effect of this fuel is based. I think if that had been afforded in such a way that an engineer could have applied his own judgment to the facts before him, we might then have had means of measuring the comparative values of coal and the other materials.

Captain SELWYN: For myself I beg to observe that I gave all the information which was at my disposal with regard to the experiments in America; and I promised, as Professor Paul will perhaps recollect, that as soon as the report is issued in February, or as soon as I receive it, it shall be laid before the Institution.

Rear-Admiral Sir E. BELCHER, C.B.: I should like to venture one or two observations with reference to the question of heating power. We all know that where we get light we obtain flame, and according to the oxygen consumed, we obtain increased heat. We know that oxygen combined with hydrogen affords us the oxy-hydrogen blow-pipe, which instantly fuses metals. If we obtain a simple vapour from petroleum which affords an intense light, we obtain, by any process which enables us to consume more oxygen, increased heat; and I believe there are few people who know anything about the oxy-hydrogen blow-pipe or the lime-light, or any intensely-powerful flames which melt a shilling in an instant, who do not know that it is due to increased expenditure of oxygen. If, therefore, we have a new mode by which a blow-pipe action causes a greater expenditure of oxygen (as we can see by a simple blow-pipe with a candle), it is due to the additional oxygen consumed. I have only to ask the gentlemen here present if they will produce any coal under the sun that will thus fuse metal instantaneously.

Mr. ROBERT MALLET, F.R.S.: May I be permitted to make one or two observations? I confess myself a believer in the future of liquid fuel as regards navigation. Nearly four years ago I pointed out, in the pages of the "Practical Mechanics' Journal," the principal points which have been urged to-night in favour of liquid fuels, and which I still hold to be as important as I ever did. This is not merely a question, as has been well put by one of the previous speakers of the theoretical heat-giving value of a particular fuel. It is, I think, unfortunate that liquid fuel has been called "petroleum" here to-night, as being too limited a word, for I believe that hereafter liquid fuel, such as we are here talking about, will be artificially obtained from the distillation of our wasted and otherwise worthless small coal, and not obtained merely from the natural wells, and therefore it conveys an undue limitation to call it petroleum. However, whatever we may call it, this is *liquid coal, minus* a certain quantity of carbon. Now, although it may be perfectly true that the carbon is theoretically the most valuable portion of the coal for heating purposes, yet you must take into account *all* the conditions under which a fuel must be burned if you would find what is its value or its valuelessness for steam navigation or any other purpose. In the first place, you must consider what you have to carry when you burn coal Recollect that every pound of fuel less, that you have to carry, is not merely so much

dead load saved, but is weight taken out of one scale and put into another, because the place of the coal is given to freight. So that even at the low price of coal, it may turn out that the dearer fuel is yet enormously the most economical fuel on the whole. There are other conditions upon which its superiority rests also. Upon a computation based upon practical data, I have come to the conclusion that of every five tons of coals put on board our steamships, only four tons are really available as used fuel; one-fifth of the fuel is lost, and either goes up the funnel as black smoke, drops through the bars as small coal, and is thrown out with the ashes, or is lodged in the flues or tubes in soot or ashes, and forms a jacketing material to hinder the heat from passing into the water. Therefore in estimating the relative values of coal and liquid fuel, you have to add one-fifth at the first blow to the purchase value of the coal, because that is the proportion of waste. You have also to bear in mind that in burning coal, you must produce fine ashes. If you have got a slow draught the ashes lodge at the lower sides of the flues and tubes. A thin film of ashes not one-tenth of an inch thick, is sufficient, as Mr. Joule's experiments indicate, to rob the coal or other fuel of an enormous proportion of its potential effect; or a film of lamp black not thicker than a sheet of paper is sufficient to reduce the heat-transmitting power in the flues of a boiler to an extent which I will not state precisely, but which is extremely large. These two difficulties are got rid of by the use of liquid fuel if burned properly; but to burn it properly, you must never trust to a slow draught, which was what I understood to have been advocated to-night. If burnt properly, you must burn it under the same conditions that you burn it in one of those lamps upon the table. You must have such control over the supply of fuel in the state of vapour or gas that you shall be able absolutely to apportion or proportion the supply of air to the gas. If you have too much gas or vapour, you will have smoke just as black as with the worst burnt coal. If you have too little, on the other hand, there will be continued loss of heat and of fuel. Now, I am not a patentee of any apparatus for burning liquid fuel, neither am I a petroleum merchant, and therefore the views I am uttering, are simply those of a man of practical and applied science. Then, as an engineer, I say that these conditions are perfectly easy to be met. I believe they will be met; and when they are, I believe the beginning of the end has been seen of coal as a fuel for steam navigation. I believe that the time will come when there will not be such a thing known as a sea-going vessel that will not carry her fuel in tanks between her kelsons. I heard some remarks made in one of the papers read, upon which I cannot avoid making an observation, though rather aside from our direct subject. A recent paper by Mr. C. W. Williams, on the inutility of tubular boilers, was quoted. I have read that pamphlet carefully, and I believe it would be scarcely possible to condense within the same space a larger amount of error than is contained in that paper. May I, be permitted to make use of the board in order to illustrate this in one point? The main gist of Mr. Williams's paper is that that part which he calls the FACE PLATE, that is to say, that side of the fire-box of a locomotive or marine tubular boiler, from which the tubes proceed, but which we have been hitherto in the habit of calling the tube-plate has been always ignored by engineers and by everybody but himself, its first discoverer—that this is the all-important thing in such a boiler, and that the tubes themselves are in fact worth nothing. To prove this experimentally he had a tubular boiler divided into a number of compartments by means of septa. Suppose this to



represent the base of a locomotive boiler (see figure) the first department was very narrow, only one inch long. Next to which was the so-called face-plate or tube-plate, out of which the tubes started. The other compartments were each about a foot long. He then states the relative proportion of water evaporated from each compartment in a given time, and from these relative amounts evaporated, he draws the amazing conclusion, that the tubes are valueless. Now let any one refer to the original paper, and upon the horizontal line representing to scale the lengths of those compartments drop down ordinates, proportionate to the evaporative power of each, and draw a curve through their extremities, and he must be convinced at once that the very contradiction of Mr. Williams's conclusion, is the legitimate one from his own premises, and admitting those to be correct. In fact the curve is one of the parabolic order, and proves that the value of the tubes is a function of their length and of the heat that reaches any point, and that this is true until we may have extended the length of the tubes to a point where the gases passing through, have reached the boiling point of the water in the boiler, or that no residual heat is left to keep up the draught. Mr. Williams's supposed discoveries hence cannot properly be quoted either in favour or against liquid fuel.

Captain HOSEASON, R.N.: I should like to ask a question of one of the gentlemen who have lectured to-day. I should like to ask if that experiment at Woolwich was an experiment carried on to the entire satisfaction of the Government Officers, with reference to which, he stated that the evaporating power of the oil was five times that of ordinary fuel, because that is a practical fact, and it is far more valuable to argue upon practical facts than upon theories which we have to-night found are very difficult to follow, from the abstruse way in which the gentlemen reason about the question. Is that a fact which has satisfied the Government officers at Woolwich? as I presume no experiment was carried on at Woolwich without the authority of the Admiralty; and if the experiment has been carried out to the satisfaction of the competent Officers whom I know to be there, I shall feel, like many other people, that a valuable truth has been stated in regard to petroleum this evening. I confess to be perfectly ignorant of the subject. I am now given to understand that the questions are not to be answered until after the close of the observations. I will then assume the fact to be stated as a *bonâ fide* fact; I will accept it as proved that the power of petroleum is five times that of coal, and then the other points become a very simple matter of computation. The power obtained by the combustion of all coals is well known. Hardly any novice in engineering, or any Officer in command of a steamer, is incompetent to state generally what is the evaporating power of coal, or what is its duty in miles per ton; if we can state the fact—that five times the power is obtained by the use of petroleum, we have the distance accomplished from here to Australia without stopping one single moment for coal. But we have a still more important result obtained; we have the effect on the immersion of the ship. I have had an opportunity of carrying out a series of experiments, by which I found that with half the power, on a favourable line of immersion, I have obtained nearly the maximum velocity of the steamer. Moreover, there is this favourable circumstance, that there will be nearly one line of immersion, by which we avoid first starting too deep, and at the end being too light. Now, from experiments, I have found a difference of four knots an hour caused by the slip of the wheel. Not having had the opportunity of experience with a screw, I cannot tell what the effect would be in that case; but this shows how a naval architect, in building a vessel, will have a far less variable line of immersion. If the distance is only 3,000 miles, all that may be turned to account in increasing the speed of the vessel, for it is more important to carry cargo than coal. For instance, in Cunard's vessels the price obtained for carrying cargo is £7 a ton: with the screw propeller it is about £3 a ton; and at the same port on the same day it is 15*s*. a ton in a sailing vessel. I have another question to ask; it seems to me a very important one. Is petroleum safe? Do these experiments that you have carried on at Woolwich justify the safety of the thing? For it is only to-day I have heard half a dozen people, in speaking of petroleum, not deny its advantages in combustion, but deny in a great measure the safety of it on board a man-of-war. Now, if it is safe, and can be used with this economy, there is no question of the great advantage to be derived

from its use. We know the enormous space which coal occupies, and if this can be replaced by lighter goods—for nearly everything you carry is lighter than coal—it would be a great advantage; and then it would be in the power of the Admiralty to establish one or two depôts to accomplish all the circumnavigation of the globe.

The CHAIRMAN: I would ask the gentlemen who have given us this interesting information this evening, in the first place, whether they are in a condition to answer one or two questions that have been put to them, especially the questions which have been put by the last speaker respecting the experiments they have tried on the safety of petroleum.

Mr. RICHARDSON: The question has been asked, "Is petroleum safe?" I think completely so; but, like gas, or every natural product we are acquainted with, dangerous if used ignorantly. We must make ourselves acquainted with its proper use, to be quite safe. The vapour, like common gas, will not explode, unless suffered to collect in a confined space, and mix in certain proportions with the atmospheric air, and then inflamed by a light being taken to it. Here is a bottle of petroleum. If I empty it, and while a small quantity of vapour remains inside, I hold it upright and apply a light to the mouth, there is no explosion; but, if I turn the bottle upside down, and put my light inside the mouth, there is an explosion. If a red-hot cannon shot were to enter a tank of petroleum, it would not set it on fire, it would merely vapourise the oil. If the tank was in a ventilated place, the cold vapour would escape harmlessly; if, while the oil was vapourising, a light was taken to the tank, only such superficial portion of the oil as was exposed to the air would take fire; it could be extinguished immediately by shutting off the air,—there would be no explosion: but if, while the oil was on fire, the tank was upset, the larger surface of the oil exposed to the air would be one mass of flames. The thinner the depth of the oil, the sooner the flame would expire,—it would flicker and go out like a flash of gunpowder. It might float over wood, and the wood would not be burned, but everything combustible caught by the flame would come to grief. In reply to Mr. Mallet, petroleum does submit to mechanical management; the engineer has a complete command over it, as well as of the quantity of air to be supplied. It may require very nice management. I believe that this grate of mine will be improved, until the oil burns as in that lamp. Our rough coal-boilers are not suited to the purpose, but as every engineer knows, the requirements for burning a new fuel are not immediately settled.

Captain HOSEASON: You let fall an expression that you assimilate it to gas. You do not take it positively in that light?

Mr. RICHARDSON: Yes, it is a gas.

Captain HOSEASON: I happened to be at Homburg, and I saw there building a theatre of wood, to be lighted by gas, adjoining a magnificent salon. A small escape of gas caused the immediate destruction of property to the value of £6,000. I apprehend it cannot be true that the man-of-war will be subject to the same thing. I know another case where the place was full of gas, and the whole house was blown to atoms. Will you state what the difference is that constitutes its safety, because if it is like gas, it will instantly explode when you bring a light to it.

Mr. RICHARDSON: No dangerous amount of vapour can escape from petroleum secured in proper iron tanks. If the spirit was first extracted, no vapour could be formed at all, except within the furnace, when in action. With regard to my experiment at Woolwich, it was not the official trial. I had a grate fixed in the boiler ready to give it up to the officers preparatory to the official trial, and I was seeking after them for that purpose, when my engineer carelessly lighted the fire in the grate, and put it into a full blaze, and then fixed the safety-valve of the boiler at ten pounds pressure. The maker of the grate had told me that it would stand a twenty pound pressure, but after doing what I have described, it opened at the joints. Mr. Trickett, the head engineer, appeared satisfied with the power of the oil, and said that the fault of the trial not coming off fully, was owing to the weakness of my grate.

Captain SELWYN: I may say a few words with regard to those parts of the experiments which attach to me, and leave Mr. Richardson to answer as to what he has been responsible for. In the first instance, with regard to the "unsinkability" of

which I have spoken. The size of the coal-bunker is very great, and if a shot goes into it you have a great amount of danger there. As to the possibility of explosions, we must not suppose for an instant that danger is entirely absent, even where coal is used. Many cases of spontaneous ignition in coal-bunkers are well known, and there is the fact, that red-hot shot will inevitably ignite coal. The whole mass of coal would be in a flame which it would be impossible to check; therefore, we must not put too much weight on the fact that, under some peculiar circumstances and certain conditions, large quantities of petroleum vapour might be ignited. But you may avoid such conditions, in proportion as you lower the vaporizable effects, by distilling off the light spirit. The danger might be removed by taking proper precautions. Mr. Paul said a good deal about the chemical bearing of the question, but he was so well replied to by Mr. Wright that I need not answer his objections. But, in addition to what Mr. Wright said, I beg to instance something which is very familiar to every chemist. Here we have gas burning under certain conditions; here, again, we have it burning under other circumstances quite different. This is the Bünsen burner, and when we get the oxygen properly admitted to that gas, we obtain an intensely heating flame, showing clearly that the question as regards heating, is entirely one of the proper combustion, and that it is not sufficient to say that this coal, or that coal, or that oil, cannot be burned at all, because it has not yet been burned. Until Bünsen discovered this burner, people were not aware in the laboratory of the value of gas as a heating power. Ordinarily we have it passing up a tube under different conditions, as a simply illuminating flame. So we have petroleum here acting in these lamps as an illuminating flame; and it is quite likely, too, that a plan corresponding to that for developing the heating power of gas, may be applied to petroleum. Sir Edward Belcher speaks of coal not being able to melt metal; neither is it capable of producing the heat which this would produce under other than exceptional circumstances. You must get a strong draught, and you must consent to waste a large quantity of the fuel. The observations which Mr. Mallet made with reference to the remarks of Mr. Wye Williams on tubular boilers I cannot answer, of course, except by drawing his attention to the fact that it is not alone Mr. Wye Williams who speaks in this way, but the whole of the engineers for the last eighteen months. Mr. McConnel has told me that he tried experiments on boilers with very similar results, and others who practised with him, and who have experimented in the same direction, agree with these results. Although it may be true that under certain circumstances the tubes have been proved to be the best means of obtaining heat, yet I am sure that Mr. Mallet has seen, as I have seen constantly, the tubes in a steamship's boiler almost filled up, so that no more than the thickness of a pencil could be passed through the mouth of the tube in the front smoke-box, from the ash which had collected, and which apparently laid there in obedience to a wire drawing action of the flame. It appears to take, from circumstances which I do not think we quite appreciate, a spiral, or cork-screw course. The tubes become choked up, and in some parts of the tube you find these accumulations of dust. It has been very well observed that a very small deposit of lamp-black, or dust of unconsumed substances, is sufficient to greatly reduce the action of the heating surface, and, therefore, any boiler which is subject to such deposit, is not perfect. Mr. Richardson has, of course, answered Captain Hoseason with regard to the experiments at Woolwich; and I may state that I have the strongest confidence in the honour and honesty of the American engineer who has communicated the letter to me, and I do not believe he would have transmitted the account, unless the results were reliable. We must recollect that the value of a fuel for steam ships does not depend altogether on its chemical calorific value, or its heating power alone, but also that there are several sources of economy, which multiply themselves as they go on, and therefore you hardly know where to stop in putting items down on the credit side of the question. It is not even alone the economy of space or the economy of fuel which is to be considered, but it is more, the enormous value of being able to do that which we never could do before under any conditions. It is also, as Captain Hoseason has very well said, a question of the immersion of our ships. In screws that is not, perhaps, such a serious matter as in paddles, but it is very important even in screws, and it means a difference in the value of the area of push due to the less density of the

water. As you approach the surface, you get the whole of the screw moving in a water of less density, the column of pressure being no longer the same. With regard to the danger of crude petroleum, I think I have answered it by saying, that the dangerous portions may be abstracted, but I also answer it practically by taking this oil, which is very much lighter than crude petroleum: it is the oil distilled by the manufacturers for the purpose of burning in lamps, and if you put a lighted match into it, it goes out. With a red-hot shot even, or a live coal, there will be white smoke proceeding from it which will not inflame, and the match also will go out as you saw now, and as I have seen a number of times myself. The danger of explosion is dependent almost entirely on specific gravity. With some specific gravities it does inflame and does explode. With others it does not; but that is a matter easily regulated, and quite within the bounds of a necessary economy, to regulate.

The CHAIRMAN: I believe I only express the general feeling of this meeting, when I sincerely thank the gentlemen who have given us this interesting information this evening. Nobody can attend to the subject of petroleum, which, I believe has only come into general use within the last five years, without seeing that it is an important one as regards the two questions which are essential to the civilization of the country, namely, light and heat. Cheap light and cheap heat are what we want for almost every purpose. Now, with regard to the application of petroleum for the production of steam in ships, I should say that we are not quite advanced to that point, at which I should be prepared to adopt a new boiler for the purpose in the Navy. We have, however, seen so many alterations in the last few years, that I do not know but that in the course of a few more we may see our coal boilers again altered for the purpose of burning petroleum. Whenever that comes, we shall remember with gratitude the interesting information we have received this evening, and trace back the commencement of this change in the Navy to the discussion which has now taken place.

Evening Meeting.

Monday, March 6, 1865.

Lieut.-Col. T. St. LEGER ALCOCK, Vice-President, in the Chair.

NAMES of MEMBERS who joined the Institution between the 20th February and 6th March.

LIFE.

McClean, J. B., Lieut.-Col., Engineer and Railway Volunteer Staff Corps, 1*l*.

ANNUAL.

Cawkwell, W., Lieut.-Col., Engineer and Railway Volunteer Staff Corps, 1*l*.
Hobart, Hon., A. C. Capt., R.N., 1*l*.
Campbell, J. A., Lieut., Royal Horse Artillery, 1*l*.
Hawkshaw, John, Lieut.-Col., Engineer and Railway Volunteer Staff Corps, 1*l*.
Bidder, G. P., Lieut.-Col., Engineer and Railway Volunteer Staff Corps, 1*l*.
Bythesea, J., V.C., Captain, R.N., 1*l*.

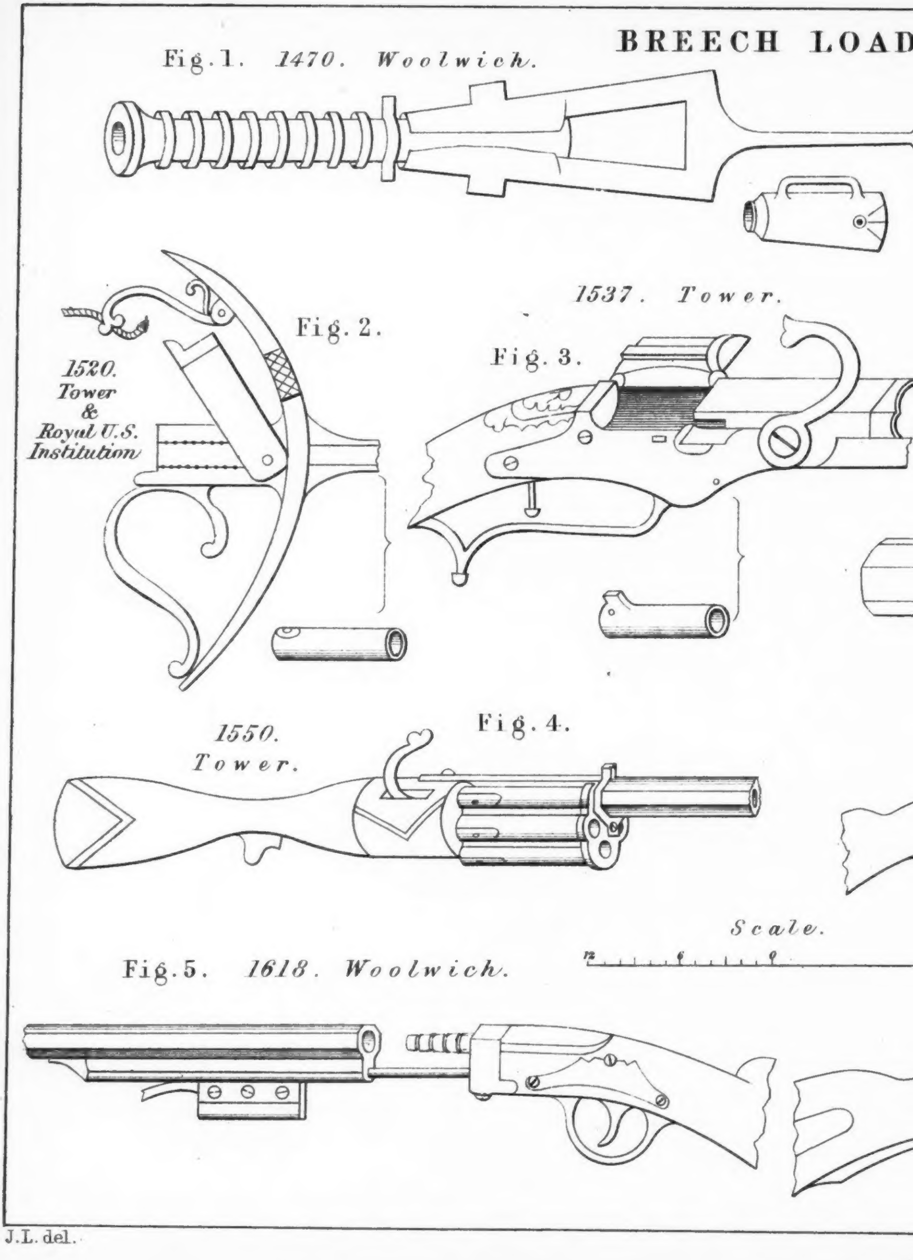
EARLY BREECH-LOADERS.

By Mr. John Latham,

Of the Firm of Wilkinson and Son, Pall Mall.

The Chairman: It is hardly necessary for me to go through the usual form of introducing Mr. Latham, for he is already well known to you by the interesting lectures that he has given at this Institution. His last paper was read in 1863, upon some of the sword blades in the Exhibition of 1862. He previously read, in 1862, a paper "upon the shape of sword blades," both of which papers have been published in our *Journal*, and have been highly appreciated both in this Institution and by the public. I shall now call upon Mr. Latham to give us his promised paper upon "some early breech-loaders."

At the present time, when the question of breech-loading is attracting so much attention, and the day-dream of inventors for the last three


BREECH LOAD
Fig. 1. 1470. Woolwich.
Fig. 2.
1520.
Tower
&
Royal U.S.
Institution
1537. Tower.
Fig. 3.
Fig. 4.
1550.
Tower.
Scale.
Fig. 5. 1618. Woolwich.

J.L. del.

LOADERS.

1619. Woolwich.

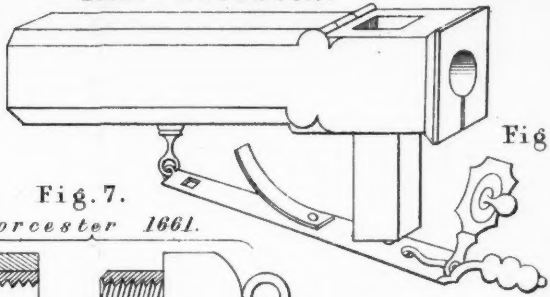
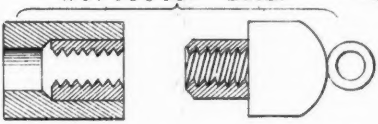


Fig. 6.

Fig. 7.

Worcester 1661.



1664. Hill and Woolwich.

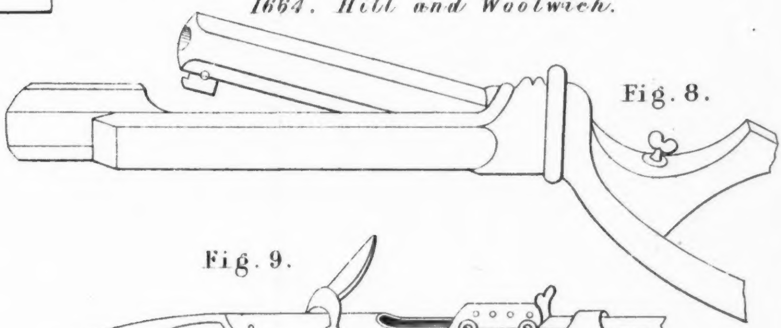


Fig. 8.

Fig. 9.

1664. Hill and Woolwich.

e.

1 FOOT

Fig. 10.

1700. Cut Screw.
(Düringer aus Mainz.)
Woolwich.

J.R. Jobbins

centuries has at length become an established fact; when this principle, having survived the opposition of its over-cautious opponents, and the more fatal advocacy of its too sanguine friends, is at length adopted almost exclusively for sporting purposes, and the only question which remains to be considered is whether its partial, shall precede its total adoption for the army; I may venture to hope that a brief account of the principal early forms of breech-loading, which exist or are recorded in the museums of invention near London, may not be unacceptable. I propose, first, to give a short description of such of these contrivances as possess any distinguishing characteristics; and next, by a general examination of the whole, to trace the succeeding stages of invention, and discover, if possible, the causes which have so long retarded their adoption.

Whilst the general public have, certainly, an impression that breech-loading is—like gas, the steam-engine, or electricity—one of the novelties of the present day, all military men are aware that it dates from a very early period in the history of fire-arms; but I think that few except those whose attention has been specially directed to the subject, give our ancestors credit for the persistence, as well as the ingenuity and variety of their contrivances in this branch of invention.

In one of the most elaborate and complete works on the subject of modern fire-arms, "Wilcox on Rifles and Rifle Practice," published at New York, in 1859, it is stated that "Henry II., of France, was the inventor of breech-loading arms, in 1540." The same assertion has been repeatedly made in French works on gunnery, though not in quite so unqualified a form, but the slightest investigation of the subject shows it to be an error. Breech, or rather chamber-loading guns, of the 15th century, are found in many of the continental museums, and, to go no farther than the door of the Tower armories, in London, we shall find a group of early cannon rusting in the open air, among which are some very curious specimens of breech-loaders. In the museum of artillery at the rotunda at Woolwich, there is a breech-loading pierrier, or paterera, of the time of Edward IV. (1461 to 1483), which is shown in the drawing (Plate XV, Fig. 1). This consists, you will observe, of a directing barrel, terminating in a square bar or frame of iron, and a separate loading chamber with handle which was fastened in its place for firing by a quoin or wedge of wood or metal.

Guns of a construction very similar to this are to be found in the museum of this Institution, and also at the Tower of London, having been recovered in 1836 from the wreck of the "Mary Rose," which sank off Spithead, on the 18th July, 1545, in an engagement between a French fleet of 150 large and 60 small vessels, and the English fleet of only 60 sail, commanded by Viscount Lister, in the "Great Harry." During the battle the "Mary Rose," commanded by Sir George Carew, was so overpowered by the weight of her ordnance that she sank, and the commander and crew of nearly 600 men were lost.

But it may be suggested that it is only the invention of breech-loading for small arms that is implied in the passage I have quoted,

and that these early cannon should be considered separately. Even with this qualification I cannot admit that the claim is any better founded, for in the same year in which Henry II. of France ascended the throne, Henry VIII. of England, died, a prince who was himself the inventor of many contrivances relating to fire-arms, and throughout whose reign the greatest attention was paid to the improvement of artillery and arms. In this reign brass cannon were first cast in England, and two foreign engineers in his service invented shells, or firework to break in pieces hollow shot, "whereof the smallest piece hitting any man would kill or spoil him."

It is, probably, to the early part of Henry VIII.'s reign that we should refer the very curious pistol-shields or "Targetts sheilde with Gonnes," of which many specimens exist in the Tower, but no examples of the kind have been found in any foreign collection. Of these, certainly the earliest form of breech-loading small arms known, I have a specimen on the table, from the museum of this Institution. It is also shown in the drawing, Fig. 2.

The shield is probably intended to protect the gunner in firing from the small loopholes of fortified places, called *meurtrières*, and the barrel generally occupies the centre of the shield, in place of the boss or spike, which is usually in this position. There is a small aperture covered with a grating in the upper part, for the purpose of taking aim, and a handle in the lower half enables the gunner to direct the weapon. A separate loading chamber, containing the charge, is pushed in at the breech, and a cross-bar or frame, which turns on trunnions, is shut down and retained in its place by a spring or bolt, to secure it whilst firing. If you compare this plan with that of the breech-loading peterara, you will see how very simple is the adaptation of the method already in use for cannon.

The principle of a separate loading chamber, inserted at the breech and held in its place by a frame with wedge or bolt, having been tried and found successful, it only remained to apply the same contrivance to the harquebus or hagbut, and fortunately, a very fine specimen in the Tower Armoury shows us exactly how this was done, and gives us the date of its manufacture, 1537. In this weapon, the loading chamber has a projecting piece above the touch-hole, to insure its corresponding with the pan of the matchlock, and is held in its place by a hinged door, which is sufficiently long to enable the chamber to be inserted and withdrawn. (See Fig. 3). It is ornamented with the king's initials, and a rose crowned, supported by two lions. These are on the fixed breech, above the loading chamber, together with the armourer's initials, W. H., and the date, 1537. Not only the ornament but the accuracy of workmanship of this weapon is very remarkable. The bore of the chamber is ·55, and of the barrel ·535, and the greatest variations from these measurements I have found is only sixteen-thousandths of an inch. When we consider the rude tools which were in use at this date, the accuracy both of the boring and fitting of this early weapon is surprising and in strong contrast with the workmanship of many arms of a much later date.

A larger weapon, of similar date and construction, said also to have

belonged to the king, but of inferior workmanship, is in the Tower, (Catalogue No. 3). This has a much larger bore, ·79, and is furnished with a spring-bolt as additional security to hold the hinge piece. The barrel is 3 feet 6 in. long, and it is styled in the early catalogues, the "Fowling peece" of that monarch.

Among breech-loading arms, we must class revolvers, whether guns or pistols, and of these there are specimens extant as early as the middle of the 16th century. One of these having a revolving breech for four charges to be turned by the hand and fired with a matchlock is in the Tower Armoury (Class 12, No. 14), and is shown in the drawing, Fig. 4. A similar and very curious weapon, but of later date, the stock richly inlaid with ivory and mother-of-pearl, with a revolving breech pierced for eight charges is in the Museum at Woolwich.

In the Tower Armoury there is a weapon (Class 14, No. 6), which is curious as an illustration of the origin of the revolver. It is a mace with four short "hand gonnes" fixed in the handle. Each barrel has a sliding cover to the touch-hole, and was fired by a match held in the hand. The shape and size are precisely those of the early revolver. We have merely to add the matchlock to this weapon, and make the fixed barrels to turn upon a centre, and we have exactly the form and construction of the revolver (Fig. 4). We may fairly conjecture that in this way the revolver originated, as the application of a later improvement to a weapon already known and in use, and this shows us how simple may have been the first idea and successive stages of improvement in a weapon, which in its modern form appears to be one of the most complicated of inventions.

In the Museum, at Woolwich, there is also what has been a very choice and rare specimen—the only breech-loading *wheel lock* arm I have ever met with. The arrangement of loading chamber, &c. is precisely the same as that of the larger matchlock arquebus in the Tower, and it is fitted with the tubular back-sight—common about 1580. The wheel lock has a very neat and ingenious safety stop or spring, to secure it from accidental discharge. It is much to be regretted that this very rare weapon has suffered improvement to such an extent, that it is impossible to compare its workmanship with the earlier specimens in the Tower, but it has been cleaned and polished, till all trace of the original workman's hand is lost, whilst the stock has been replaced by one of mahogany, a wood hardly known in England until many years later. I think that these specimens show us clearly, first, that breech-loading cannon were known and used in England during the latter part of the 15th century, and that during the 16th century a modification of this plan was applied to small arms. I hope to show, in the course of this paper, that the plan thus early adopted has survived in principle to the present day, and is now among the best known and most successful of our modern plans of breech-loading.

The commencement of the 17th century was a stormy time in Europe. The outbreak of the thirty years' war in Germany, the minority of Louis XIII. in France, with its endless revolts and conspiracies, and the accession of James I. in England, so soon to be

followed by the troubles of the Civil War and Commonwealth, introduce us to times in which we may expect the arts of war to receive special attention.

The earliest breech-loading arm of this period with which I am acquainted is to be found in the museum at Woolwich. It is a flint lock musket, and bears on the barrel, which is nearly 4 feet long, the following somewhat pompous inscription in French:—

"Model of one of the projects of Fusils. Composed and proposed "by Le Sieur Berthier, 1618, of the camps and armies of the king, "attached to the suite of the Minister of War—executed by De "Sainte."

The mechanism, which is very simple and effective, is shown in the drawing (Fig. 5). Here we have still the idea of the loading chamber, but it is attached to the stock instead of being removable, and the barrel slides forward to enable the charge to be inserted. This arm is also very interesting, as being one of the earliest specimens of the flint lock, though there is one in the Tower which precedes it by about four years. There are three other breech-loaders in the collection at Woolwich of about the same date as this, and in which the idea is of the same kind. The barrels, generally upwards of 4 feet in length, are jointed at about 6 inches from the breech end, so as to enable them to be loaded more conveniently.

The next specimen, also from Woolwich, is the first in which we find the loading chamber dispensed with, and the charge inserted directly into the barrel itself. It is in fact, the first direct breech-loader as distinguished from a chamber-loading piece, and let me call your attention to the fact that this step in advance, simple and obvious as it seems, required the assistance of a secondary invention to render it practicable. The loading chamber could be charged with loose powder and ball, but the contrivance of a cartridge was necessary before an actual breech-loader could be employed. This weapon is a breech-loading wall-piece, or rampart-gun, of the time of Louis XIII. It bears the date of 1619, and is beautifully inlaid with gold and silver ornaments (Fig. 6). The bore is continued through the piece, and a vertical slot receives a vent-piece, which is worked by a lever handle from below. It is curious to notice, that in this early piece, two of the distinguishing characteristics of the Armstrong breech-loader are to be found; viz., the continuous bore, and the vertical vent or breech-piece. The screw which secures the vent-piece in the Armstrong is wanting, but even if this contrivance had occurred to the earlier inventor, he must have abandoned it, as the manufacturing art of that time could not have produced a screw of sufficient size and accuracy to work properly.

A wheel lock revolver in the Tower, about 1640, is the next in point of date. It is probably some such weapon which is alluded to in the following quotation from *Pepys*, who recounts in his Diary of the 4th March, 1664: "There are several people trying a new-fashioned gun "brought my Lord Peterborough this morning, to shoot off often one "after another, without trouble or danger."

But the most complete specimen of a revolver of this period I have

ever met with is in the museum of this Institution. It is pierced for six charges, and is fired by a lock of the early flint or "snaphaunce" pattern. Each chamber has a pan to hold the priming, closed with a sliding-piece, which is uncovered by the fall of the cock—and the act of cocking the piece causes the chambers to rotate—a marked improvement which, however, is wanting in many revolvers of later date.

Although not strictly a breech-loading arm, I may here mention a very curious revolving cannon in the museum at Woolwich (Class 2, No. 155), its length is 3 feet 9 inches, and it has 7 bores about $1\frac{3}{4}$ in. diameter, each of which has a vent with cover, it revolves in a collar at the centre, to which the trunnions are attached. It is probably of the period of the thirty years' war (1618 to 1640), and was no doubt considered at the time (and undoubtedly was) a very choice specimen of manufacturing art. The maker was evidently of the same opinion, and gave vent to his feelings in four lines of uncouth German rhyme, engraved upon the chase of the gun:—

> "Gotes hilf und unverdrossen,
> Hat Mich Hans Reysinger gegossen,
> Mann nent mich ein Buntzen in der Noth,
> Wirt einer aus Mir troffen—helf ihm Got."

Which may be roughly translated, endeavouring to render the quaint humour rather than the literal words of the original:—

> "By sheer hard work, and God's good aid,
> Jack Reysinger this gun hath made,
> In time of need a stout defence,
> Who feels my shot—God help him thence."

The records of the Patent Office date from 1617, and in 1661 we find that the Marquis of Worcester, a name well known in the annals of invention, obtained letters patent for among several other things, "An invencion to make certaine gunns or pistols, which in the tenth part of one minute of an houre may be re-charged; the fourth part of one turne of the barrell, which remains still fixt, fastening it as forceably and effectually as a dozen thrids of any scrue which in the ordinary and vsuall way require as many turnes." As no drawings or specimens of this contrivance exist, we can only conjecture what it may have been, but from the description, I should understand the plan which we now know by the term of a "cut screw," a plan which has been repeatedly patented since, and which is very clearly described in one of these subsequent patents as consisting of a male and female screw "having parts of their circumferences respectively cut away to the bottom of the thread, so that the one will slide home within the other, and then engage with a small turn" (Fig. 7). A very good specimen of this contrivance is in the museum at Woolwich (Cl. 9, No. 8). It is of German manufacture, and the date about 1700, and has the combined lock, to work with either flint or match, the invention of which has been generally ascribed to Marshal Vauban, though Mr. Hewitt has shown that this was known in England as early as the time of James II. (Fig. 10.)

In 1664 a patent was obtained by Abraham Hill, of the Citty of London, Esq., and Fellow of the Royall Society, which contains, among other things, suggestions for six different plans of breech-loading. The descriptions are generally so vague that it would be useless to quote them, except in two instances.

The first plan proposed is a "new way of making of a gun or pistoll, the breech whereof rises upon a hindge, by a contrivance of a motion from under it, by wich it is alsoe let down again and bolted fast by one and the same motion." There are two examples of this contrivance in the museum at Woolwich. One of these, a German breech-loading rampart gun, is shown in Fig. 8 (Class 9, No. 2), and in later years a plan of a similar kind has been frequently tried.

Another of Hill's plans is "for a gun or pistoll which is charged and primed at a hole under the sight or visier, at the upper end of the breech, and shutts within with a cartridge or roundish plate of iron, and without with the sight or visier." An example of this very curious contrivance is shown in Fig. 9, and is also from the museum at Woolwich. (Cl. 9, No. 14.)

At the commencement of the 18th century, we find a very great improvement in the application of the separate loading-chamber principle. The barrel is hinged to the stock, so as to drop forward and allow the chamber being inserted and removed without the waste of space behind the breech, which is seen in the earlier form. Fig. 3.

An example of this construction is shown in the drawing, Plate XVI., Fig. 11. It is an early rifle, by W. Fullick, of Sarum, in the Woolwich collection. There are also three specimens in the Tower Armoury, and two in the museum of this Institution.

Whilst the general principle of these arms is the same, they all vary in minor details, especially in the method of fastening the stock and barrel by a spring catch, stud, or bolt, and also in the arrangement of the touch-hole and priming; thus we find specimens (in the Tower and in this Institution) in which the chamber is perforated with a touch-hole, to correspond with the pan of the flint lock, which is fixed to the hinged portion of the stock. Next, as shown in the drawing, the chamber has a pan with sliding cover attached, to hold the priming, thus effecting a great saving of time in loading the arm, and finally, specimens (in this Institution and at the Tower,) in which each chamber has a hammer and pan attached, reducing the time of loading to a minimum.

These examples may be all included in the date from 1718 to 1740, and show that this contrivance of the hinged barrel with separate loading chamber, received great attention, and was tried with several modifications about this time.

In 1718, the fourth year of the reign of King George the First, James Puckle, of the Citty of London, Gent., obtained a patent for "A portable gun or machine called a defence, thatt discharges soe often, and soe many bulletts, and can be soe quickly loaden, as renders it next to impossible to carry any shipp, by boarding." Worthy Mr. James Puckle is in one respect a model for all inventors, since in a

.
.
.
r

d
e
,
y
n

t
r
d
e
.

,
h
d

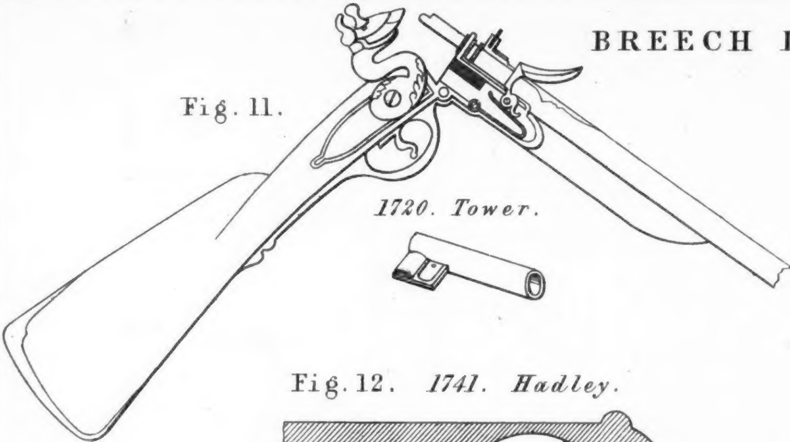
y
d
of
er
a-
ne
ne
g,
y,
ch
ng

0,
te
al

st,
or
oe
rs
ny
a

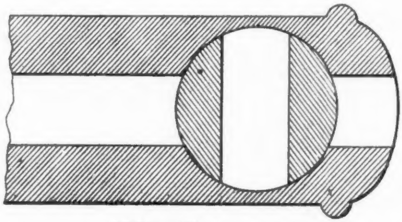
BREECH LOA

Fig. 11.



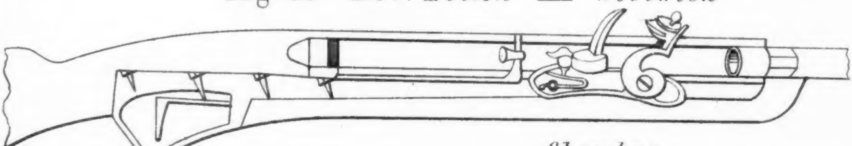
1720. Tower.

Fig. 12. *1741. Hadley.*



1776. Fergusson.

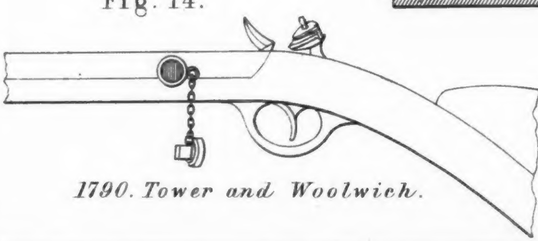
Fig. 13. *1784. Bolton — Woolwich.*



Chamber.

Section.

Fig. 14.



1790. Tower and Woolwich.

S

12 6 0

J.L. del.

LOADERS.

Fig. 15.
1800. Tower.

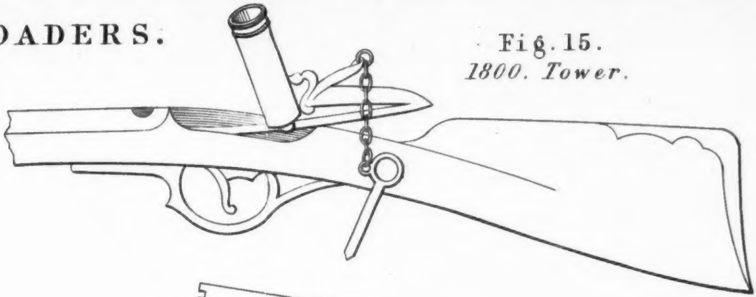
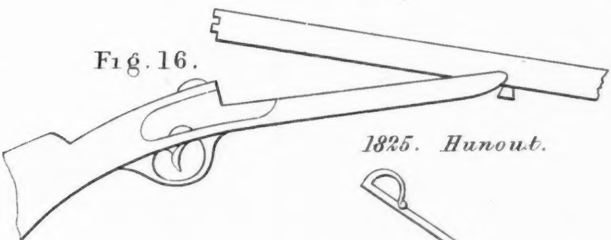
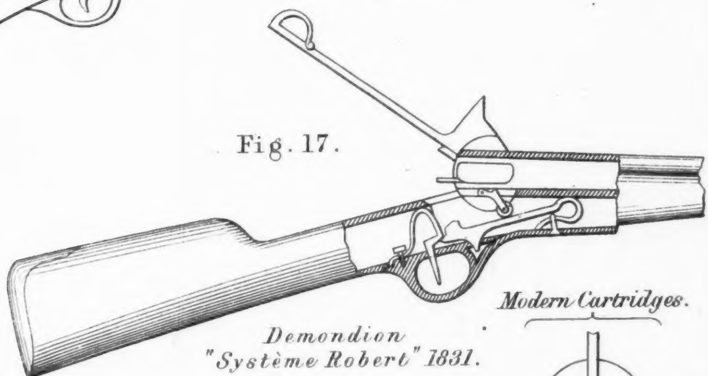


Fig. 16.

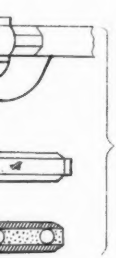


1825. Hunout.

Fig. 17.



Demondion "Système Robert" 1831.



Modern Cartridges.

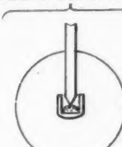


Fig. 19.

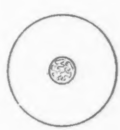
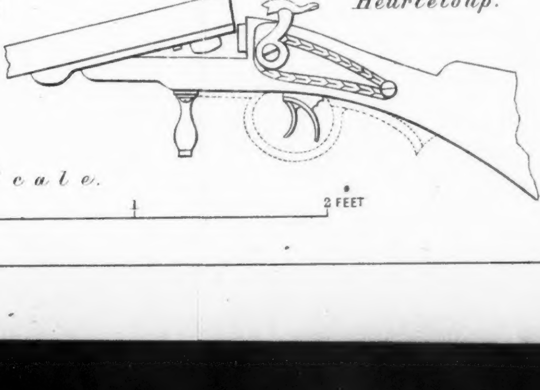


Fig. 20.

Fig. 21.

Fig. 18.
1834. Heurteloup.



Scale.

0 1 2 FEET

J.R.Jobbins.

space rather less than a sheet of foolscap, he manages to give us a very clear drawing and description of a somewhat complex revolver, and has room to spare for the lighter graces of poetry in addition. He describes the object of his invention, which he styles a defence—thus:—

> "Defending King George, your country and lawes,
> Is defending yourselves and the Protestant cause."

And the use of his invention is stated at the foot of the drawing as being—

> "For bridges, breeches, lines and passes,
> Ships, houses, boats, and other places."

His revolver, which is fixed on a tripod stand, has a central pin or screw, on which every set of chambers play off and on, and he shows a second set of chambers ready charged, to be slipt on when the first set are pulled off for re-charging.

A special set of chambers is also shown, "for shooting square bullets against Turks," and others, for "round bullets against Christians." A delicate distinction, which I am afraid would hardly be appreciated by the recipients.

About the middle of this century, we first meet with the curious magazine guns, of which the Tower collection possesses three specimens, one of Italian manufacture, very elaborately chased and ornamented. There is also one in the museum of this Institution. The contrivance is the same in all of these arms, and is very simple in its action, though difficult to describe.

I think we may safely conclude that these curious weapons were mere *tours de force*, examples of the skill and invention of their contrivers rather than intended as weapons for general use, or with any idea of their adoption in actual warfare, for which they are disqualified by the expense of their construction, the complication of mechanism, and also the danger of their employment. Magazines of ammunition contained in the weapon itself, whether self-loading or only self-priming have always two fatal tendencies, and generally end in one or other of these two catastrophes—they either stick fast or blow up, and very often the first, is the forerunner and cause of the latter accident. I must confess I have very great doubts as to whether the manufacturers of these particular weapons ever submitted them to the actual test of firing, and I know I should have far too much respect for the powers of "villanous saltpetre" to dream of trying the experiment myself. We must bear in mind, however, the very great difference in the properties of ancient and modern gunpowder, a subject which I shall have further occasion to illustrate presently.

We have next a flint lock revolving gun in the Tower collection which bears the date of 1739. If has four chambers, and is of Portuguese manufacture, but though very elaborately mounted in chased brass and silver, the construction is inferior to the earlier ones, as there is no way of loading the chambers except from the muzzle of the fixed barrel—a very tedious and defective method.

In 1741, Gilbert Hadley patented a breech-loading arrangement for cannon which has a hole athwart or across the bore, in which is fitted a moveable pin or plug, or else a *rowler*, with a hole through athwart it. During loading the rowler answers the bore, and being turned round, it becomes a full stopper of it (Fig. 12). In short this is the ordinary mechanism of a beer or water tap, and this is the earliest record of the application of this construction to fire-arms. This tap action has been very seductive to inventors, and has been patented again and again since; but when we come to classify and examine the principles of these inventions, we shall see the reasons why in my opinion it can never be a successful one.

In 1772 we have a patent by Thomas Wright, Watchmaker, and Charles Byrne, Gunmaker; the drawings attached to which show eight different methods of breech-loading, besides a great many other contrivances of magazine hammers for flint locks and spiral and other springs for the heel plates of guns, to ease the recoil, &c. The idea in all is the same, the barrel is detached from the breech to load, and can be fastened in its place by a series of spring catches or screws. I will not waste your time by any comment on these contrivances except to say that they seem very badly calculated to withstand the force and corrosion of exploded gunpowder.

In 1776, Patrick Ferguson re-patented the plan of the tap action for small arms. He also describes a plan of sight which slides on the barrel, increasing the elevation as it recedes from the eye, and a principle of rifling with very wide grooves and narrow angular lands; both anticipations of our modern inventions. This plan of rifling was re-patented as lately as 1851.

In 1784, Mr. John Bolton invented a very terrible and complex piece of mechanism, which remains as a monument of his ingenuity, and is now in the museum at Woolwich. It is a chamber loading gun furnished with three chambers, each of which holds seven charges, which are fired by separate touch-holes and a sliding lock. See Fig. 13.

To the close of the 18th century, I must refer two or three specimens of breech-loaders existing in the Tower, and for which I am unable to assign a precise date. One of these is shown in the drawing Fig. 14, and it is certainly one of extreme simplicity. A raised neck like the mouth of a bottle is formed on the left side of the barrel about two inches from the breech, by which the charge of powder and bullet are introduced, and the aperture is closed by a screw plug. As this ingenious plan takes rather longer time to load than a muzzle loader—necessitates the employment of a flask and loose charge of powder instead of a cartridge, and would become hopelessly stuck fast by the least fouling or rust; it is difficult to conceive what advantage could be claimed for it by the inventor.

Another breech-loader, of which two specimens exist in the Tower, is shown in the drawing Fig. 15. A loading chamber slides out from the breech and is thrown up to receive the charge by a spring underneath. When loaded it slides along a steel guide in the stock, and is secured by a cross pin attached to a chain; the whole arrangement is very ingenious but excessively complicated.

The beginning of the 19th century is marked by the introduction of the percussion principle patented by Forsyth in 1807. In its bearing on our present subject, we can now discern by the clear light of after experience, that this was one of the main inventions by which breech-loading has been rendered practicable for small arms. The touch hole of the flint lock was liable to be closed by the smallest accumulation of dirt or fouling, which would cause a miss fire, where the force of the percussion powder would carry a similar obstruction before it. In addition to this the percussion principle enabled us for the first time to combine the ignition with the charge in one cartridge and thus save the time employed in priming the arm which takes as long as the loading itself. But we must not be surprised to find that more than a quarter of a century elapsed before these advantages were recognized or applied. Perhaps the greatest obstacle to the introduction of the percussion principle was the complexity of the means originally contrived for its application: small magazines of fulminating powder which required constant renewal, large magazines with every variety of lever and slide action and a pervading tendency to blow up in use; Balls, pellets, plugs, patches, in short almost every conceivable complication was tried until the introduction of the copper cap in 1816. This, combining the two great requisites of simplicity and certainty, soon established itself to the exclusion of the other plans, many of which however, are constantly re-appearing at the Patent Office in the guise of new inventions.

I may here quote a remark of Mr. Henry Wilkinson, the truth of which will be acknowledged by everybody who has studied the subject—"Original inventions are generally complicated, the fear of "not having enough to effect the desired purpose is probably the "cause of beginning with too much, and we only discover after long "experience how to separate the essential from the superfluous."

Another invention of this date should be considered as connected with, and necessary to, a clear understanding of our subject. In 1815, Sir William Congreve patented a new mode of manufacturing gunpowder, and it is not too much to say, that the composition which we understand by that name dates only from this period. Of course, there were successive improvements in its composition and manufacture, extending over the whole four centuries we have been reviewing, but we find that up to 1410, about the date of the first breech-loading cannon, the composition was either equal parts of each ingredient, or else the same with an additional part of saltpetre. In 1484, Richard III. gave John Bramburgh an order for "certaine great stuffe of gunpowder," and it was not only great stuff, but sad stuff also, for the compositions I have named are about as effective as a common squib of the present day. In 1520, the date of the earliest breech loading small arms, 4 parts of saltpetre, 1 of sulphur, and 1 of charcoal were employed, and these were only mixed together with little or no purification according to the skill of the manufacturer.

In 1604 and 1607, patents are granted to John Evelin and the Marquess of Worcester, for the manufacture of "good corne powder, "both for callyver and cannon," which after the Crown is served, "may

"be sold to any of his Mats. subjects after 10*d.* the lb." The corning or granulating of gunpowder dates from this period, but as late as 1750, the proportions and method of manufacture were very defective, and the combustion comparatively slow and gradual.

This may enable us to understand how many of these earlier contrivances might be successful in their own day, although they would not stand for an instant before the lightning blast of a charge of modern gunpowder.

I shall not have to detain you much longer over the mechanical contrivances of the beginning of the present century, as with a few exceptions, a simple enumeration of them will suffice.

In 1803, Durs. Egg patented a breech-loader, of which two or three specimens are at the Tower, and one on the table. A hinged loading chamber is fastened by a lever in front, which shuts by a spring at the side.

In 1813, James Bodmer patented a plan for cannon which are closed by a conical plug, secured by a wedge-shaped cross piece. This patent also includes some ingenious contrivances for closing the vent, and balancing the sights, so that they shall be upright at any elevation of the muzzle.

In 1814, James Thomson patents a "single-barrelled and polichambered gun," and also many varieties of breech-loaders. One of these, described as a plug drawn back by a plain rod, which is fastened in its place by a siding bolt, is a very simple and effectual plan, which has been re-patented as lately as 1860.

In 1816, Samuel, Jean Pauly patents a hinged breech-piece, and also *an expanding plug*, formed of lead, copper, or such other ductile materials as will give way to the force of the charge. This is a step in the direction of the great difficulty, and we shall see how this idea has been developed in later times.

In 1817, Urbanus Sartoris patents the cut-screw, which is certainly suggested in the Marquess of Worcester's patent of 1661, and has since been patented many times, both in England and America.

In 1818, Elisha Collier patents a flint-lock revolver, which is moved by a spiral spring, like a watch, and requires to be wound up from time to time, a plan which, complex and liable to derangement as it seems, has been subsequently patented two or three times.

In 1821, the patent granted to Forsyth, for the percussion principle expired, and very shortly after the application of it took rapid strides.

In 1825, Louis Hunout patented improvements in breech-loading, which consist of a loading chamber and hinged barrel, the noticeable feature in which is, that for the first time the "charging barrel" is made to turn on centres in the forepart of the stock, instead of at, and under the breech as in the former plans. This is the earliest instance of the modern plan of hinged barrel for sporting arms, known as the "Lefaucheux" (Fig. 16).

In 1829, John Tucker re-patents the "tap" action for cannon only, and in November of the same year he patents a percussion shell

bearing a great resemblance in the mode of ignition to that of Sir William Armstrong.

In 1831, A. Demondion patents a communication from a certain foreigner residing abroad. This is the plan known on the continent as the "Système Robert," and as a specimen exists at Woolwich, and it is certainly a great advance on any previous method, and in some respects more complete than most of our modern plans, it deserves a careful examination.

The end of the barrel is closed by a framed piece turning on trunnions at the breech, and moved by a long strap extending down the stock (Fig. 17). By lifting this upwards the breech is opened, and at the same time the weapon is cocked by a projecting roller, which acts upon the main-spring. The cartridge, which contains its own ignition in a detonating tube attached, is then inserted, and the lever being shut down, the piece is cocked ready for firing. Now, here we have for the first time a cartridge containing the ignition, and a piece which is cocked by the action of opening the breech. Thus we save the time of priming and the time of cocking, and have only one movement of the hand in opening and closing the piece. This arm can be charged and discharged with fewer motions than any other yet contrived; it is very solid and substantial, and I believe that with a modification of the cartridge, it would be able to compete with most of our modern systems.

In 1831, the Marquis of Clanricarde patents a plan of breech-loading, which consists of a sliding loading chamber, elevated to receive the charge, and secured by a wedge and lever to hold it whilst firing. A specimen of this weapon is now on the table. The cartridge is very peculiar, being built up of many sections, like the segment shell of Sir W. Armstrong, and the arm which is a pistol, is made bell-mouthed, so as to scatter these pieces as widely as possible. It is curious that there were several wall-pieces taken at Bomarsund, during the Crimean war in which this plan of breech-loading has been adopted.

In 1831, Abraham Adolph Moser patented the first needle gun, which in its construction and details is a very close resemblance to the Prussian weapon, which the late war in Denmark has made so famous. The projectile is fixed in a pasteboard case or *sabot* behind which the detonating powder is placed. The needle strikes through a tube which passes through the powder chamber, and so ignites the charge in front. This is precisely the construction of the needle gun invented by Dreysa, of Sommerda, in 1835, and adopted in the Prussian army—there is a later improvement in which the breech-loading arrangement occupies a much smaller space, and the needle strikes through the charge of powder, the directing tube being dispensed with. Specimens of both these arms are on the table.

There is a description and drawing of the Prussian needle gun in Lieutenant Walker's paper on "Breech-loaders for the Army," read at this Institution on the 6th of June, 1864, and also in Sir Howard Douglas's Work on Naval Gunnery; but there is one distinguishing peculiarity of the cartridge, which I have never seen noticed. It is

this, that the bullet never touches the barrel during the firing—it is much smaller than the bore of the barrel, and is contained in a pasteboard *sabot*, which alone takes the rifling and communicates its rotation to the bullet. Thus we have no appreciable wear, and perfect cleanliness always ensured. The cartridge contains its own ignition, which is thoroughly secure from accidental explosion.

With regard to the construction of this arm, there is also a peculiarity which deserves notice. It is the *cheapest* breech-loading arm yet contrived, and for this reason, that it is the first arm which does not require the special skill of a gunsmith to make it. The lock can be made by any engineer or workman, accustomed to lathe work; no special nicety of fitting is required, and any carpenter can make the stock. In short, we might consider the question of military breech-loading as satisfactorily solved in this weapon, but for one misgiving, Will it shoot? That is, is it equal in accuracy to the muzzle-loading Enfield on the one hand, or the muzzle-loading Whitworth on the other. We are not likely to accept of any arm which shoots worse than the first, and we have not yet found any arm which shoots better than the last. The question of the accuracy of the weapon has never yet been tried, and I hope that some Prussian gunmaker will be tempted by the offer of £100 by the National Rifle Association, and will send over one of the famous needle guns to compete in the trial of May next.

In 1834, Baron Heurteloup patented several improvements in firearms, which are distinguished by a high degree of originality and ingenuity. In investigating the subject of detonating powder, he discovered that a certain composition which he specifies, can be cut through with a sharp edge without danger, while it instantly explodes when struck with a blunt surface. He proposes to put this composition into tubes, which are afterwards flattened into a sort of tape, and gradually advanced over the nipple. A portion being cut off by a sharp edge attached to the hammer, is struck by the head and ignites the charge. This is of course liable to the objection to all magazines—that they run out and are exhausted, generally when least expected and at the most important moment. But his plan of breech-loading is a very good one for sporting arms, and is well known at the present day. The barrels lock into two projecting plugs at the rear end, and move forwards and upwards on the stock to receive the cartridge (Fig. 18). This movement is effected by an eccentric bolt actuated by a lever attached to the trigger guard. This movement, with only a modification of the position of the lever, has been re-patented within the last few years, and is well known among sportsmen, as the "Lock fast" principle. Heurteloup's patent also describes an expanding base to the cartridge, formed of wood or lead, and cup-shaped to expand with the explosion.

In 1835, Samuel Colt, took out the first patent for his famous revolver, which was afterwards modified by further contrivances; although as we have seen, revolvers are found of as early a date as 1550, there is no doubt that the modern adoption of this principle is mainly owing to the improvements of Colt.

In 1836, the plan generally adopted for all sporting arms was introduced by Lefaucheux, of Paris, the barrel is hinged on the forepart of the stock, as in Hunout's plan of 1825, it is secured by a lever in front of the guard, as in Heurteloup's plan of 1834, and it is worth while inquiring why a plan which contains at first sight no distinguishing features, should have obtained such ultimate and general adoption, while its predecessors are forgotten. The answer is, that the invention here lies in the cartridge, which not only contains its own ignition (as in Robert's plan of 1831), but also, and for the first time, completely closes the joints of the barrel during the explosion, and secures them from the action of the powder. It is, in fact, more than a cartridge—a complete loading chamber of pasteboard and copper. And we may pause a moment to notice how simply the problem which had defied the skill of mechanicians in past ages, and which could not be effected by any contrivance of iron or steel is solved by this simple tube of paper and copper. The action of the powder no longer destroys the fitting of the joints and the question of breech-loading, as regards sporting arms at least, is solved.

In 1837, a revolver, on what is known as the wheel principle, was patented by Moses Poole. There is a specimen of this contrivance on the table. It is inferior to the ordinary revolver in compactness, and also in safety, and I only notice it to mention, that it has been re-invented by our cousins in America, and figures in the Woolwich Museum as Colonel Porter's revolving carbine, 1854 (Class 10, No. 33).

We have now arrived within about a quarter of a century of the present time, and, as my subject is only the earlier forms of breech-loading, I must here conclude my enumeration of the different plans proposed. If we investigate the succeeding years, we shall find, as has been clearly pointed out by Mr. Benet Woodcroft, the Superintendent of Specifications, "that five-sixths of the applications (for "patents) relate to old contrivances which have been patented over "and over again," but we shall also find a few, which, like the admirable contrivance of Mr. Westley Richards and some others, occur at intervals to prove, that novelty of principle as well as construction is still possible. But the subject of modern breech-loading, and its application to military purposes is under the consideration of abler heads than mine, and I will now proceed to a very brief general consideration of the plans already named.

First, let us endeavour to classify them—beginning by separating those which have a distinct loading chamber from those which are loaded directly into the barrel. The first kind we will call chamber loaders, and we must distinguish them according as they have the loading chamber separate or attached to the barrel or stock. The remainder, which load at once into the barrel we will call direct breech-loaders, but the sub-division at first seems nearly impracticable, from the great variety of their mechanism. But if we consider a little, we shall see that there are really only three ways of closing a barrel, and regarding only the way in which the aperture is closed, without including the means adopted to secure the closing-piece, we can divide

them into these three heads. First, the barrel may be closed by a plug or plunger, precisely as the mouth of a bottle is closed by a cork —next it may be secured directly by a cross-piece, wedge, or bolt; and lastly, it may be secured by a tap, having an aperture movable on its axis.

Applying these distinctions to the plans here enumerated, we may construct the table as shown on pages 104-5.

Now on considering this table we shall see how the plan of a detached loading chamber, combining the two great requisites of simplicity and safety, was the first to suggest itself, and after being employed for cannon for about half a century, was, by a very simple modification, adapted to small arms. A century later, the contrivance of the hinged barrel rendered the loading more convenient, and after the lapse of another century Lefaucheux's contrivance of a pasteboard chamber or cartridge brings us to the present development and general use of this principle.

In the meantime, the attached loading chamber had received several modifications, but up to the present time has not met with general adoption. In later times the best known and most successful breech-loader, on this principle, is that of Mont Storm.

Of direct breech-loaders, the plug or plunger action has been most frequently tried, and it is superior to either the wedge or tap action, for this reason—that the bearing or frictional surface is limited to the circumference of the bore. In the wedge action, the extent of friction is generally nearly *four* times the circumference, and in the tap action more than *nine* times, and as the friction of moving surfaces is the greatest obstacle we have to encounter in the mechanism of breech-loading, you will see why these latter plans have met with so little attention.

At the present time the plug action is represented by the Westley Richards and Terry—both actually in use in the British army—by the Prussian needle gun, and by Green's, Cooper's, and many other less-known plans. The wedge action by Sharp's, was formerly used in the service, but is now abandoned. The tap action has no representative in modern military plans.

But there is another hint which we may gather from the examination of these early plans. The loading-chamber principle, though known for three hundred years, only came into general use when a suitable cartridge chamber was contrived for it. The plug action, which has come into use of late years, is fired with a cartridge having a wad of felt at the base.

This acts as an elastic washer in front of the joint and secures it from the action of the powder during explosion, in fact, this modification of the cartridge renders direct breech-loading practicable, precisely as the pasteboard chamber first rendered chamber-loading practicable. And this leads directly to the point I wish to urge upon you, viz., that a good cartridge is of more importance in breech-loading than the mere mechanism of the arm, and that it is in this direction we must mainly look for improvement at the present time. When we have got a cartridge that completely fulfils the three requirements of certainty,

safety, and durability, it will be easy to find a dozen different plans of breech-loader to fire it.

The future of breech-loading is undoubtedly in the direction of cartridges carrying their own ignition, since by retaining the copper cap we lose half the advantage of quick loading. Of these, which we will call percussion cartridges, we have three plans at present before us. These are the pin, the needle, and the rim cartridge,—my time will only permit the briefest possible description of them.

The pin cartridge has a movable pin projecting from the edge, the lower end of which rests upon a copper cap, enclosed in the cartridge, and is exploded by the blow of the hammer (Fig. 19). This plan is certain and durable, but has been objected to, for military purposes, on the score of safety, though it has now been in use some thirty years, amongst sportsmen, without any serious accident, and surely the soldier, who is daily practised in the use of his arm, can be taught to be at least as careful as the sportsman, who only uses a gun two or three months in the year.

In the needle cartridge the percussion powder is placed in the centre and is ignited by the blow of a needle or movable punch attached to the lock (Fig. 20). This plan has equal durability and greater safety, but is not quite so certain as the former. The blow of the needle may displace or penetrate the fulminating powder, without exploding it, though this is only liable to happen if the powder has deteriorated by time. But there is one objection to all guns on the needle principle which I have had forced upon my attention in a very unpleasant manner, namely by the passage of a bullet through my coat on one occasion, and within a foot of my head at another time. It is this, that in a needle or central fire breech-loading gun, you cannot see on taking up the weapon whether it is loaded or not. The projecting pin of the Lefaucheux, or the copper cap on a muzzle loader, bespeak caution in an unmistakeable manner, but in the needle gun and similar plans, this advantage, which is a very important one, is lost.

In the other cartridge which has been lately introduced, the percussion powder is placed round the rim of the cartridge, and explodes by being struck or rather pinched between the edge of the barrel and the hammer head (Fig. 21). These have safety and durability but want certainty. At least this is my own experience of them. The difficulties in their construction are greater than in either of the other forms and I do not think these have yet been satisfactorily overcome. There are many points in the construction of cartridges which require a much more careful consideration than they have yet received, but to enter on this question would require a whole evening and I must therefore pass them over. I may mention, however, that loaded cartridges containing gunpowder and fulminating powder in contact with metal deteriorate rapidly by time. After two years keeping the failures will average 10 per cent. I am so convinced of this that I make it a rule to condemn all cartridges which have been loaded twelve months.

There is only one other point on which I should like to remark, and it bears upon the question of breech-loaders for the army. In so vast a change, we must be guided to some extent by the question, not

what is theoretically best, but what is most expedient. I have already stated my opinion, that the future of breech-loading lies in the percussion cartridge with contained ignition, but as many months, if not some years, must necessarily elapse before we can supply breech-loaders for the whole of our troops, and at any intermediate time we may have to go into action with the two different systems of breech and muzzle-loading in operation, it is of the greatest consequence to avoid any chance of confusion. If, therefore, we can get a transition arm suited to a transition period, we should avoid the chance of great complications. Now any breech-loader which is fired by the copper cap, can be used upon emergency with muzzle-loading ammunition of the same bore, but this is at present impossible with any plan in which the cartridge contains its own ignition. Whether this difficulty will be removed by any mechanical contrivance, or whether it will have sufficient weight to influence the decision of the committee now sitting, and to what extent, I cannot foresee, but I must confess it seems to me the greatest difficulty of the whole question. Of muzzle-loading ammunition we have an enormous quantity in store. Can this be utilized? Of muzzle-loading arms we have thousands. Can these be converted to breech-loaders? Can it be so arranged that during the transition period, there shall be no chance of our soldiers finding themselves armed with breech-loading weapons, and only muzzle-loading ammunition procurable? These are very grave questions, but they are no doubt receiving the fullest consideration. And when the decision is made known, we must not be surprised if we find that the question is advanced rather than settled; that it will show us, not how far we might go, but only how far we can go with safety at the present time.

CHAMBER LOADERS.

Detached.		Attached.	
1537	Tower.	1618	Woolwich 3 plans
1650	Woolwich.	1664	Hill, Woolwich
1720 to 1750	Tower, R. U. S. I., and Woolwich.	1803	D. Egg.
1825	Hanout.	1831	Clanricarde.
1836	Lefaucheux.		

BREECH-LOADERS DIRECT.

Plug or Cone +	Wedge or Block +	Tap or Cross Bolt.
1661 Worcester. 1772 Wright. 1814 Thomson. 1816 Pauly. 1817 Sartoris. 1831 Moser. 1835 Prussian. 1840 Bush. 1849 Ritchie. 1850 Sears.	1619 Woolwich. 1813 Bodmer. 1831 Demondion, or "Robert."	1741 Hadley. 1776 Ferguson. 1841 Golden.

REVOLVERS.	MAGAZINE GUNS.
1550 Matchlock. 1640 Wheel-lock, Snaphaunce. 1717 J. Puckle. 1739 Tower. 1818 Collier. 1835 Colt. 1837 Poole (wheel gun).	1740 Tower and R. U. S. I. 1781 Woolwich. 1847 Taylor.

The CHAIRMAN: Before I proceed to propose a vote of thanks to the lecturer, which I am sure you will all be delighted to give, I will take upon myself to say that Mr. Latham will be ready to answer any question that may be put to him. If any one will avail himself of the opportunity, we shall be very pleased to hear him give us his opinion upon the important subject that has been introduced. Perhaps it may be within the knowledge of some gentlemen present that some of these forms of breech-loaders have been used in actual warfare. If so, it will be of great interest to hear information upon the subject, and also with reference to the more recent forms of breech-loaders.

PETER JOHNSON, Esq.: With regard to the breech-loader, dated 1790, I think it was a German invention, which was used in the first American war. I am only speaking from memory as regards a book which I possess, in which there is a principle which appears to me to be precisely similar to the one the lecturer has described. First of all, the powder and bullet having been put in, the charge was cut off afterwards by a screw. But I was not aware that it was a screw attached in that sort of way by a chain, apparently. I have not seen the book for years, therefore I am only speaking from memory.

Mr. LATHAM: I think your description would apply better to this plan by Ferguson, 1776 (showing specimen from Museum of Royal United Service Institution) in which the screw goes completely through the barrel, and thus cuts off the communication with the breech; but in the one shown in the drawing (Fig. 14), the screwed cap merely closes an opening in the side of the barrel.

Mr. JOHNSON: Yes, this arm (Ferguson's) would be the principle to which I am referring.

Rear-Admiral Sir F. Nicolson, Bart., C.B.: I had not the least intention of making any observations on this occasion, for I am, I dare say like many others present, somewhat ignorant of breech-loading rifles. But I should be very sorry if this meeting separated without some member of the Council expressing very great approbation of the lecture which we have heard to-night. I think I have rarely heard a lecture given in this Institution which seems to have been so carefully prepared, and in which the lecturer has evidently taken such elaborate pains to bring forward everything that could illustrate the subject he had to place before us. The only regret I have is, that Mr. Latham has dwelt so entirely upon the arms of an old date, and he has shown us that there is "nothing new under the sun," for with regard to every single breech-loader that he has got there, I think I have seen something very like it brought forward at the present day, I am only sorry that he has not been able on the present occasion to tell us something more of what is going on at the present time. I dare say many of the gentlemen here present have, like myself felt, that to go out with a muzzle-loader in company with men who have got breech-loaders is perfectly absurd. You feel yourself at a disadvantage, and you naturally take to the breech-loader in preference to the muzzle-loader. It really seems almost difficult to imagine why there should be this great length of time in arming our Army and Navy with breech-loaders. It seems to me that a man going out to shoot men, goes out to perform very much the same operation that a man does who goes out to shoot pheasants. All he wants to do is to hit the object he points at, and to be able to load easily and without any delay. I suppose there are a great number of difficulties in the way; and I must say I never tried a breech-loader myself until a very few weeks ago, and the facility of the operation struck me at once. You have nothing to do but to move a lever, push in your cartridge, and the thing is done. When you see an unhappy skirmisher who has to fire an immense number of rounds, and has to be hammering at his bullet that won't go down, with a heavy ramrod, it is very evident that the man wants a different kind of arm. I hope, therefore, that the time is rapidly approaching when we shall be able to arm both our Army and Navy with something that will enable them to load with great rapidity, and then to fire with greater precision; for we all know, that to have to hammer away at a tight fitting bullet, destroys your ability to take a good aim. The great objection I believe to the introduction of breech-loaders into the Army, at least one that I have heard named, is that the men would fire away their ammunition too rapidly. Now that is a fault which I believe is the case with all young troops especially; and the only thing to be done is to teach them not to fire away too rapidly, to teach them that the great object is to hit and not simply to fire. In the old days the great object was to fire rapidly whether you hit or not. I therefore hope that on some future occasion Mr. Latham will be able to give us a lecture not upon these ancient and curious arms, but upon the more modern improvements of the day.

Chairman: I have now to convey to you, Mr. Latham, the thanks of the meeting for the important, interesting, and very amusing lecture which you have been kind enough to give us.